SCIENTIFIC AMERICAN SUPPLEMENT

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VOLUME LXXVIII]
NUMBER 2031

NEW YORK, DECEMBER 5, 1914

[10 CENTS A COPY
$5.00 A YEAR

The garden city of the employees at the works of Messrs. Lever Brothers, Port Sunlight, England.

Entrance to the village of old pensioners at the Krupp Works, Essen, Germany.

Workers' cottages at the Krupp Works, Essen, Germany.

EFFORTS FOR THE WELFARE OF WORKMEN IN EUROPEAN MANUFACTURING ENTERPRISES.—[See page 360.]

Electric Furnaces for Heating Steel—II*

Facts and Figures Relating to New and Valuable Methods

By Alcan Hirsch

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2030, Page 339, November 28, 1914

THE temperature and the production of steel from an electric furnace are mutually dependent. The heat liberated in the resistor, if not taken up by the metal, will occasion a rise in temperature of the furnace. The larger the electrical capacity per unit of hearth, the greater the effect on the temperature by alteration in the production. It is for this reason that productions over 50 pounds per hour per square foot of hearth should be avoided. With moderate capacities of 4 or 5 kilowatts per square foot of hearth area (equivalent to a production of 30 to 35 pounds of steel per hour to 1,700 deg. Fahr.) variations in production have but very little effect on the temperature. The heat capacity of the resistor lining and brickwork in furnaces of this size is amply able to compensate for changes in production, so that the temperature remains practically the same. A furnace designed for a normal running load of 4 kilowatts per square foot of hearth (with 1½ volts per inch length of the resistor) will prove very satisfactory. The uniformity of temperature on the hearth in furnaces employing the T-shaped resistors shown in Fig. 3 is quite remarkable, but even with the U-shaped or serpentine resistor a temperature variation of less than 10 deg. Fahr., in any point of the hearth from the desired temperature, is to be expected.

Enameling furnaces fall quite in the same category with the heat-treating furnaces. Although they are larger in size they are not correspondingly large in electrical capacity. For enameling furnaces resistors should be placed on the sides, but about three-quarters of the kilowatt input should be liberated in the base. Resistors when placed along the sides of a muffle of an enameling furnace should be small, 10 to 20 square inches in section and should consist entirely of graphite. The lining of such a resistor is usually designed so as to form a part of the interior wall of the muffle.

ELECTRIC FURNACES FOR TEMPERATURES ABOVE 1,800 DEG. FAHR.

With respect to the class of furnaces operating over 1,800 deg. Fahr. the writer knows of no example in industrial work, except on a small scale, which has proven satisfactory. A number have been constructed and tried for various lengths of time, but a durable furnace, certain of operation, is yet to be produced. Most of the experiments which have been conducted have employed furnaces with a single resistor about half graphite and half charcoal, as mentioned above. These resistors have been made about a foot and a half wide and placed in a trough of a mixture of refractories, the basis of which is firesand. The metal to be heated was placed directly above the resistor, but not touching it. The metal was steel bars for forging and heated to about 2,400 deg. Fahr. In order to effect a production similar to that of an oil-fired forge furnace of the same size, the temperature of the resistor had to be above 2,900 deg. Fahr. For this temperature it seems impossible to construct a furnace which will have a very long life. In the course of a few weeks the lining or the bricks will have fluxed to some degree and rebuilding will be found necessary. A lining of substantially pure silicon carbide brick might stand up under these conditions, but it is questionable if a refractory any poorer than this would be satisfactory. The electrodes, too, are difficult to hold in place without costly supports which might have to be water-cooled. These furnaces have been used for heating metals for forging and have shown in some instances good economy. A current consumption of 370 kilowatt hours per 2,240 pounds of metal on a 100 kilowatt furnace was noted. In general, the type of construction on these furnaces was similar to that shown in Fig. 2, except that the U-shaped resistor was substituted by a single straight one running from one end of the hearth to the other.

For work at forging temperatures a furnace employing a graphite resistor does not seem capable of becoming a commercial reality unless a very unique lining can be developed.

ELECTRIC FORGE FURNACE OF THE ARC TYPE.

The writer has given considerable thought to this important field of electric furnaces for forging and has developed a furnace which appears to eliminate most of the difficulties encountered. This furnace is as yet only in the experimental stage, although it appears to offer attractive commercial possibilities. It is of the arc type and thus immediately many of the difficulties inherent to the resistor furnaces disappear. As there is no resistor there is, of course, no resistor lining. The metal is placed on the hearth and is heated directly by the arcs, the bases of which play a few inches above the metal to be heated, thus obtaining a high thermal efficiency. The arcs are deflected by means of an auxiliary electrode which spreads the flame of the arcs so as to distribute the heat comparatively evenly and also serves to protect the roof of the furnace. The roof, if built of silicon carbide brick, will have a long life. As the electrical equipment is placed above the hearth it is easily accessible and may be removed by a crane so that a new top can be placed on the furnace in a very few minutes. As arcs of a few kilowatts are difficult to operate, it would probably be necessary to build a furnace capable of a very substantial production. The writer hopes that definite commercial data regarding this furnace can be secured very shortly.

DESIGN OF FURNACE FROM STRUCTURAL STANDPOINT.

Fig. 3 shows a heat-treating furnace of 125 kilowatt capacity under the normal running load. It has a maximum capacity of 175 kilowatts. The hearth is 5 feet wide and 9 feet long inside.

A very satisfactory furnace wall has been found to consist of two bricks laid so as to make 9 inches and with 3 inches of kieselguhr. The kieselguhr may be placed between the bricks forming a vertical channel, or may be placed outside the bricks, in which case, sheet metal is employed for the outside of the furnace to hold the kieselguhr in place. Asbestos mill board may be used in place of sheet metal. This does not lower the heat losses, and, of course, the mill board is not quite so durable as the sheet metal. Furnaces may be well insulated on the top and sides of the hearth, but care must be observed not to insulate the base too well. It must be recognized that in electric furnaces the heat is evolved within the brickwork and is, consequently somewhat different from the fuel-fired furnaces. Hence, the furnace should be set clear of the floor with only about 15 inches of brick allowed up to the lining on the base of the resistor. Ten or 12 inches are quite sufficient for this dimension for furnaces working above 1,700 deg. Fahr. The brick employed should be good fire brick. Silica brick serve excellently for this purpose. These brick run about 95 per cent silica and contain a little lime. Good masonry work and particularly well constructed arches will be much the cheapest in the long run. Throughout the furnace construction the same principles as are observed in oil furnace design are, of course, applied to electric furnace construction.

It is most important to select the proper refractory for the lining of the resistor. The lining is usually in the shape of a trough, the resistor being placed in it. The lining material must have a high melting point; it must not have a high vapor pressure at its operating temperature; it must not react chemically with the hot resistor on one side or the brick on the other; and it must not become soft or "mushy" at the operating temperature. Its electrical conductivity at the operating temperature must be considerably less than that of the resistor and it must be relatively cheap.

The operating temperature of the lining is rather high, normally a few hundred degrees higher than the hearth temperature, but for various reasons the maximum temperature obtained in a lining may be a thousand or more degrees higher than the normal operating temperature. The reason for obtaining these high temperatures in the lining may be due to neglectful operation or an attempt to get an extraordinarily large production at a particular time. It is, therefore, necessary to employ a lining having a high factor of safety as regards the temperature. It is exceedingly difficult to find a material which meets these requirements at a temperature of 2,000 deg. Cent. (3,632 deg. Fahr.). It must be remembered that although refractories of high melting point are available, the addition of the necessary binder, even though in small amount, may lower the fusing point of the lining very materially. Either of the following substances[6] having high melting points might be employed as the principal constituent of a refractory for use in a furnace operating above 2,000 deg. Fahr.

Refractory.	Melting Point. Deg. C.	Deg. F.
Calcium carbide (boils at 2,015 deg. Cent.)	1995	3623
Aluminium oxide	2020	3668
Uranium oxide (U_2O_3)	2176	3946
Uranium carbide	2425	4396
Zirconium oxide	2500	4532
Vanadium carbide	2750	4982

In addition two other substances should be mentioned. Glucinum oxide has a high melting point, and boron nitride shows no sign of sintering at 3,000 deg. Cent. (5,432 deg. Fahr.).

Magnesium oxide begins to vaporize under atmospheric pressure at 2,009 deg. Cent. (3,650 deg. Fahr.). All metallic oxides are somewhat acted upon by hot carbon, and as the speed of reaction approximately doubles for every 10 deg. Cent. rise in temperature at electric furnace temperatures this chemical action is often sufficient to deteriorate considerably if not destroy the lining entirely. At about 2,000 deg. Cent. (3,632 deg. Fahr.), magnesia is rapidly attacked by carbon.[5]

The electrical conductivity of lining materials, especially metallic oxides, increases very rapidly with the temperature. Materials which are excellent insulators at room temperatures become fine conductors at electric furnace temperatures and this should be borne in mind in connection with the linings. For example, a slab of alundum (fused alumina) had a specific conductivity[4] at 1,600 deg. Cent. (2,912 deg. Fahr.) about 50,000 times as great as at 20 deg. Cent. (68 deg. Fahr.).

In the writer's experience silicon carbide firesand offers advantages over other refractory materials for the linings of furnaces considered in this paper. A mixture of silicon carbide firesand 85 parts, and water glass (38 deg. Baumé) 15 parts, forms a good lining when well baked in the furnace. A slightly better lining can be made by using the above mixture for the outside of the trough and pure silicon carbide with the water glass in the same proportions for the inside next to the resistor. The lining is put in place with the assistance of wooden forms, and allowed to dry; when the furnace is started it becomes well baked. At operating temperatures such a lining is a much poorer conductor than graphite, and there is practically no chemical action between it and either the carbon or silica brick with which it is in contact. Silicon carbide begins to decompose at about 2,300 deg. Cent. (4,172 deg. Fahr.) into carbon and silicon, which vaporizes, but it has given excellent service over a considerable period of time. A silicon carbide lining, properly built in a heat-treating furnace designed to give a hearth temperature of 1,850 deg. Fahr., should not need renewal more often than once in six months and frequently such linings last much longer. It will be seen, however, that linings are relatively expensive items in furnace construction so that the firesand is probably the most economical, particularly if 1,700 deg. Fahr. is the maximum hearth temperature desired.

The writer begs to suggest that the question of linings for this type of furnace offers an attractive field for research and he sincerely hopes that scientific work along these lines will be made by investigators.

Electrodes are placed in the furnace imbedded in a mixture consisting of silicon carbide 90 parts, tar (melting point 100 deg. Fahr.) 10 parts. They project from the furnace wall about 6 inches into a box without a top and made of asbestos mill board with a framework of small angles attached to the furnace. The leads are run into the box from the top and are clamped to the electrodes. The box is then filled with kieselguhr. The electrodes may be of either graphite or carbon, preferably the former. The size of the electrodes may be calculated by the well known methods,[7] and either the square or round form may be used.

The switchboard has a main switch, and a radial switch with a number of points, if a transformer is used. The switching may be accomplished on the high tension

*Author's abstract of report on research carried out under a Carnegie Fellowship granted by the Iron and Steel Institute of Great Britan. The complete report of this work was presented at the Annual Meeting of the Institute, May 7th, 1914. This abstract is reprinted from the *Journal of Industrial and Engineering Chemistry*.

[6] "Fusion and Volatilization of Highly Refractory Materials," Ruff and Goecke, *Z. angew. Chem.*, 24 (1911), 1459.

[5] O. P. Watts, "Action of Carbon on Magnesia," *Trans. Amer Electrochem. Soc.*, 11 (1907), 279.

[4] E. F. Northrup, *Metal. Chem. Eng.*, 12 (1914) 125.

[7] The writer believes the best method for determining the proper cross-section of electrodes is contained in an article by Carl Hering, "Empirical Laws of Furnace Electrodes," *Trans. Amer. Electrochem. Soc.*, 17 (1910). Table VI in this paper may be employed very satisfactorily for the calculations.

or the low tension side of the transformer, as is desired. If regulation is effected by altering the resistance with a furnace such as is shown in Fig. 3, knife switches alone are used, as no transformer is employed. The resistors are thrown in or cut out by single bladed knife switches, as desired. An ammeter is employed in all cases unless the primary tension is too high to warrant satisfactory operation of same. The ammeter is, of course, always placed on the primary side of the transformer. If an ammeter cannot be used a wattmeter may be employed, or it may be used if an ammeter is not desired by the operator.

Wiring should be quite carefully done and with sturdy construction. The chief precaution to observe is to insulate all conductors of current and have such insulation located so that the furnace heat will not injure it. In most cases it is preferable to run the conductors down from the electrodes along or beneath the floor to the switchboard. The switchboard, of course, must be accessible to the operator of the furnace, and is preferably placed by the side of the furnace near the end having the door.

Operation of an electric furnace of the graphite resistor type is found to be very simple. A new furnace is started up slowly, the voltage equivalent to one volt per inch length of the resistor being applied for about 12 hours. At the end of this time it may be brought up to temperature by gradually raising the voltage per unit length of the resistor. The metal is passed through the furnaces, the operation being quite the same as in the fuel-fired furnace, and with a very little experience the proper load for each particular job may be readily ascertained. If a change in the production of steel occurs in the furnace, or a change in temperature is desired, it is advisable to raise or lower the kilowatt input, as the case may be, about 15 or 20 minutes before the change occurs. Otherwise, failure to get the production on the one hand, or failure to get the temperature on the other, may be the result.

When the furnace is to be shut down the current may be turned off 15 or 20 minutes before the last piece of metal is removed. The furnace is then closed and as it is quite hot, will take but a short while to heat up after the usual over-night shut down of 14 hours. The time to heat up after such a period is from 20 to 30 minutes. To heat the furnace up from cold requires about one hour.

As previously stated the resistor burns away partially and must be replenished. This should be done at intervals of about 70 hours of operation on furnaces operating from 1,700 deg. Fahr. to 1,800 deg. Fahr., but furnaces running at lower temperatures will last for longer intervals without replenishing. At 1,700 deg. Fahr. hearth temperature the consumption of graphite is approximately 0.01 pound per kilowatt hour. The graphite may be charged through small port-holes, located in the sides of the furnaces, by means of long handled scoops. It is then raked down with a small rake adapted to the particular resistor.[8] In some instances the resistor runs uncovered or partly uncovered along the sides of the hearth in the interior of the muffle. In this case the graphite is shoveled in through the furnace door. The proper amount of graphite to be used will be found readily by a few trials, noting the position of the switch before and after charging for the same load.

As the regulation is accomplished by simply throwing the switch, the furnace may be regulated by the workmen. The wiring, of course, must be arranged so that it is impossible to short-circuit the line by means of the switches. The workmen, however, must be instructed not to run the furnace on a voltage equivalent to 1.8 or 2 volts per inch length unless the production really warrants it. Otherwise, overheating may sometimes occur between charges while the furnace is empty. To provide against overheating in this manner, fuses should be carefully selected of low amperage, which is determined by the maximum rate at which the work should be done. This precaution is to be observed particularly on furnaces where productions are varying widely from day to day. For temperatures over 1,800 deg. Fahr. it might be advisable to equip the furnace with a pyrometer constructed so as to operate a circuit breaker when the maximum desired temperature is reached.

EFFICIENCY.

Although the furnace has been designed with the idea of supplying enough current to heat the metal and to make up the losses of radiation, etc., the superintendent of the heat-treating department is very likely to consider the furnace from a standpoint of efficiency. This may be expressed in per cent of kilowatt hours per unit of production. Table II shows the relation between these two methods of expressing efficiency.

In general, the larger the production of metal in a particular furnace, the greater the electrical efficiency.

[8] The upper surface of the resistor should be raked as level as possible, but it is better to have it slightly concave laterally than convex.

TABLE II—NUMBER OF KILOWATT HOURS REQUIRED TO RAISE ONE TON (2,240 POUNDS) OF STEEL TO VARIOUS TEMPERATURES AT SEVERAL EFFICIENCIES.

Rise in Temperature.		Percentage Efficiency.				
		50	60	70	80	100
		Kilowat. Hours Required.				
Deg. F.	Deg. C.					
950	528	89	111	127	148	178
1050	584	103	129	147	172	206
1150	639	118	147	168	196	236
1250	695	134	167	191	223	267
1350	750	150	187	214	249	299
1450	806	164	205	235	274	328
1500	834	171	214	245	286	342
1550	861	178	223	254	297	356
1600	889	188	235	268	313	376
1650	916	197	246	282	328	394
1700	945	207	259	296	345	414
1750	972	217	271	310	362	434
1800	1000	222	278	318	370	445
2350	1306	272	340	388	453	544

Too high production, however, usually means difficulties in control and with very high production there is danger of overheating should there be slackening in the production without a corresponding change in the kilowatt input being made. The aim to make a production at a rate equivalent to 4 or 5 kilowatts per square foot of hearth and also at 65 to 75 per cent efficiency is an excellent one. When the cost of current is rather high, work which necessitates a production at a lower efficiency than 60 per cent should be transferred to a smaller furnace if the shape of the pieces permits. On furnaces under 30 kilowatts capacity these figures do not apply, as the efficiency on such small furnaces is very much less than on the moderate size ones of 50 to 125 kilowatts.

INSTALLATION OF FURNACES.

In order to determine the number and size of furnaces for an installation a careful inquiry into the nature and quantity of the production is necessary. The maximum and minimum productions must be met with as high efficiency as possible for the various productions. Frequently a moderately large furnace to operate all the time, accompanied by a smaller one to be operated as needed, is much more economical from a point of view of current consumption in the long run, than one furnace capable of the maximum production. Care must be observed not to make the furnace too large for the sake of being on the safe side. A furnace so large that it takes 10 per cent more current than a smaller one exactly suited to the work, would waste enough current in the course of six months, or a year at the outside, to pay for a complete new installation. Sometimes the labor requirements determine the size of the units. Two men on a single furnace might not be able to accomplish so much on the one furnace as they would if operating two smaller size furnaces. Here the decreased efficiency in two furnaces must be carefully compared with the saving in labor.

SELECTION OF TYPE OF FURNACE.

In the selection of the type of furnace for the particular work, if 10 square feet or more of hearth area are required, a furnace regulated by the resistance method, Fig. 3, is certainly to be preferred. This furnace costs about half as much as the furnace equipped with a transformer and has a much more uniform heat liberation in the hearth. Electric furnaces with resistance regulation including all the electrical equipment, cost about the same for installation as a good oil furnace, and frequently are somewhat cheaper if blowing equipment installation charge for the oil furnace is included. As a rule these furnaces operate on a higher voltage than do the furnaces having a special transformer so that a saving in copper for the conductors is sometimes effected. They can be designed to operate on the standard voltages, 220 volts being very satisfactory, and, of course, can operate on either direct or alternating current. The larger furnaces can be built to operate on two- or three-phase lines, but those taking 100 kilowatts or less are best constructed for single-phase or direct current. For the small furnaces, such as the one shown in Fig. 4, a regulation by means of voltage is best with a transformer having a secondary with several taps, as mentioned above, either with or without the resistance regulation in conjunction with it.

USE OF ELECTRIC FURNACE FOR HEAT TREATMENT DEPENDENT ON THE COST OF CURRENT.

The extent of the use of the electric furnace for heat treating depends quite largely on the cost of current. Fortunately, in this connection, the resistance furnaces have a remarkably steady load. The starting load is somewhat less than the running load. In a large number of cases the mean running load is found to be between 80 and 90 per cent of the maximum demand. Under these circumstances, particularly with operation extended into or through the night, current can usually be furnished for a low figure. The price of one cent per kilowatt hour is frequently sufficient to warrant the employment of the electric furnace in place of oil on the ground of cheaper cost of operation alone. Current for three-quarters of a cent per kilowatt hour frequently proves as cheap as any method of firing when all factors are considered. Among these factors, most of which have been duly considered, might be mentioned the lower labor charge which is usually effected by the introduction of the electric furnace. The furnace is conducive to high production on account of the fact that it is not so uncomfortable for the workmen as the fuel-fired furnaces. Besides the fact that it is relatively cool and the elimination of all smoke and dirt, and the attendant difficulties with the products of combustion, the electric furnace is much more satisfactory from the workmen's standpoint than any heretofore produced.

Musical Woods

Now that America is taking stock perforce of the materials within her own borders which may replace supplies heretofore from Europe, it is worth while noting the characteristics that lend value to certain woods for the purpose of making musical instruments. It is said, for example, that Stradivarius could never have produced his golden-toned violins but for the precious stock of choice and seasoned wood bequeathed to him by Amati.

A late number of *Cosmos* gives some interesting data on this subject. The main quality desired, is, of course, sonority and the wood chiefly utilized is that of the *epicea*, which is often confused with the fir, to which its general aspect is similar.

The *epicea* is found in a wide range of conditions growing both in flat and in mountainous country, especially in central and northern Europe.

"Like all other conifers its wood is composed of a single element, i. e., fibers or aerolated vessels, and its great homogeneity of structure renders it admirable for the production of sounds. Hence it is used for making violins, guitars, mandolins, sounding-boards, etc. Either the sap-wood or the heart can be employed, since there is scarcely any difference between these in the *epicea*, a condition which is very rare in most trees."

A valuable point with those interested in the exploitation of this timber is that trees which have grown on plains, and especially those which have grown in the vicinity of swampy land yield wood which is soft, spongy, and easily altered. Trees which carried on their struggle for existence in a rather severe climate and at a considerable altitude—800 to 1,500 meters—are much more valuable to the instrument maker because their wood has grown slowly and acquired a highly desirable compactness. It is advisable to make use only of timber which has had not less than two or three hundred years of growth, having concentric circles only two or three millimeters apart at most.

In the most valuable instruments maple is used for the "box;" for the cheap ones the tropical wood violet-ebony is employed, while for those of medium price alternate leaves of the two are used. The maple is highly sonorous, the sycamore-maple somewhat less so, as it is less compact and less homogenous than white maple. It is generally reserved for mandolins, because its rings are very apparent. Its wood is hard, of a yellowish-white tint, sometimes striped with green, it is brilliantly lustrous in radial sections. It is found in the United States, Europe and Canada. Instrument makers lay special value on *epicea* from the Swiss Jura, particularly the Vosges.

"The violet-ebony, which is much used for boxes and necks, is an exotic wood imported from India, Africa, Madagascar, and Brazil. That from Rio de Janeiro is particularly esteemed and is much used for making pianos. It is of a dirty gray color marbled with chocolate at the heart, with very visible pores, and slightly wavy stripes. It is close-grained and possesses an agreeable odor."

A great deal of ebony is also used for making dyes, twisters, strings and nuts. This wood, whose blackness, hardness and denseness are well known qualities, is also of tropic origin, but it is far less used than formerly, because of its vast increase of price in late years.

The quality of solidity, plus a definite degree of suppleness, are the features required for making bows of stringed instruments. Various tropical plants furnish this combination, especially the iron-wood, which grows in Brazil, Paraguay, the Argentine, Guadeloupe, Guiana, the Antilles, and the Malayan Archipelago. Pernambuco wood is also valued for this purpose, and grows abundantly in Jamaica and Brazil.

Marine Wood Borers

Little Known Crustaceans of Destructive Habits

By Clyde H. Truesdale, Forest Products Laboratory, Madison, Wisconsin

ENORMOUS destruction to timber structures is caused every year by the ravages of marine wood borers. These borers work in salt water throughout the entire length of the seacoast of the United States, but their ravages are particularly severe along the South Atlantic and Gulf coasts.

The damage is caused chiefly by two borers of the mollusk group, the *xylotrya* and *teredo*, and one of the crustacean group, the *liminoria*. The former are commonly referred to as "ship worms," and the latter is sometimes called "gribble." All of these borers are well known to engineers and others who are concerned in the maintenance of wharves and other structures of wood in salt water.

There are, however, two other borers of the crustacean group that are known to be present on our seacoasts. These are called "chelura" and "sphaeroma." Chelura has been reported from only two places on our coast, Woodsholl, Mass., and Provincetown, Mass. Sphaeroma has been reported from several points on the South Atlantic and Gulf coasts—Crescent City, Fla., Milton, Fla., Bay Point, Fla., Palatka, Fla., Tampa, Fla., and Bayou Bonfoncia, La.

The appearance of wood attacked by chelura is so similar to the work of liminoria that the identity of the former may have frequently escaped observation, the damage being attributed to liminoria. In *A*, Fig. 1, is shown a specimen of wood attacked by liminoria, and in *B* one attacked by chelura. In each case the size of the bore is about the same. Liminoria galleries usually extend inward, perpendicular to the surface. These are about 1/32 inch to 1/16 inch in diameter, and about ½ inch deep. They lie side by side in countless numbers, the partitions between the galleries being so thin that the wood is easily broken away by wave action, thus exposing new surface to attack. The chelura bore much deeper, and the galleries may run in all directions through the wood. They also attack the wood in great numbers, the walls between the galleries are very thin and the wood is easily broken away by wave action. As shown in the picture, the appearance of wood attacked by liminoria and chelura is very similar. Figs. 3 and 4 show specimens of liminoria and chelura very much enlarged. These borers are no larger than a small grain of rice. Liminoria excavates in wood both for food and shelter, boring being accomplished by very sharp mandibles. Chelura are somewhat similar to shrimp in appearance. They bore with an instrument somewhat resembling a file.

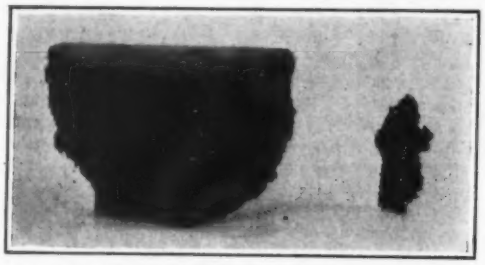
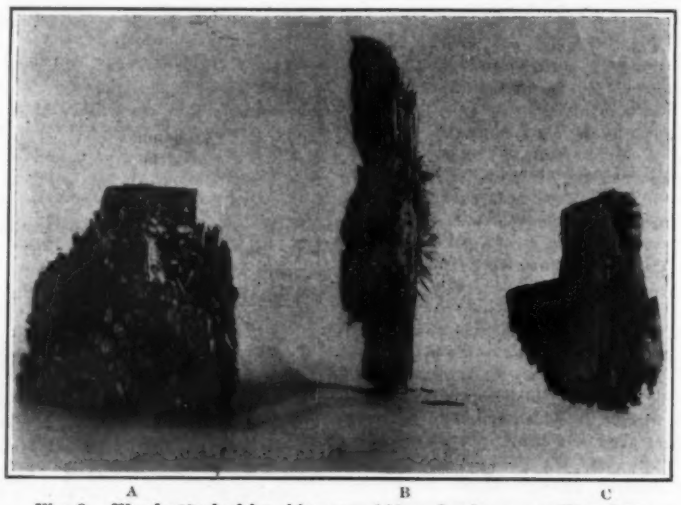


Fig. 1.—Wood attacked by liminoria (left) and chelura (right).

In the first the galleries run in radially and penetrate about ⅝ inch. In the second they run in all directions, and the entire wood structure has been penetrated.

Xylotrya (Fig. 5) is very similar to *teredo*. These borers enter the wood when very small. As they penetrate the wood, however, they grow very rapidly and the galleries increase in size to accommodate the growing body. The galleries average about 3/8 inch in diameter, and 3 inches to 6 inches in length, though under favorable conditions they may reach 1 inch in diameter and 4 or 6 inches in length. The exterior appearance of the surface of wood attacked by ship worms is often very deceptive (*A*, Fig. 2). The entrances to the galleries are



A B C

Fig. 2.—Wood attacked by shipworm (A) and sphaeroma (B and C).

Note small entrances to galleries in *A*, and large entrances in *B* and *C*. In *B* is shown attack in palmetto.

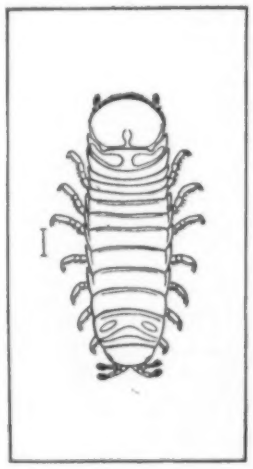


Fig. 3.—Liminoria lignorum.

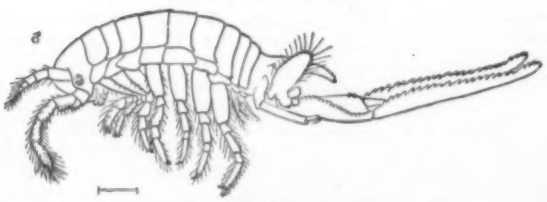


Fig. 4.—Chelura terebrans.

Fig. 5.—Xylotrya.

Fig. 6.—Sphaeroma destructor.

Fig. 7.—Longleaf pine pile destroyed by liminoria at Brunswick, Ga.

Fig. 8.—Longleaf pine pile destroyed by xylotrya at Pensacola, Fla.

Fig. 9.—Longleaf pine pile destroyed by sphaeroma at Mayport, Fla.

no larger than a pin hole, and the wood may appear to be practically sound until it is cut into, when large and numerous galleries are revealed. This is indicated quite clearly by *A*, Fig. 2. These galleries are always lined by white calcareous material. They intertwine about each other and are usually so numerous that in severely attacked specimens the wood is rendered useless for any purpose. These borers have been known to utterly destroy pine piling in less than thirty days, while the average life of piling on the Gulf coast is less than two years, if the timber is not protected from them.

Sphaeroma has long been known to mankind, and is very common in many parts of the world. It was not until 1898 however that it was known to attack wood. In that year a specimen of wood which was destroyed by an unknown borer was taken from the St. Johns River, near Palatka, Fla., and sent to the Smithsonian Institution. It was identified as a species of *sphaeroma*, and given the name of *sphaeroma destructor*. This borer (Fig. 6) is somewhat similar to the *liminoria*, but very much larger. It is about 1/8 inch to 1/4 inch long, and excavates a round gallery about 1/8 to 3/16 inch in diameter. (The animal is larger than the gallery.) The gallery is of the same diameter throughout, and is usually about ½ inch deep. Unlike the *teredo* gallery, there is no calcareous lining.

The galleries made by the *sphaeroma* are quite similar to those made by the shipworm (Fig. 2, *B* and *C*), where the surface of the latter has been broken away by wave action. Unless one makes a minute examination of the wood, their work would naturally be attributed to the shipworms. This probably accounts for the fact that *sphaeroma destructor* was never identified until 1898, and has been reported from only two or three places since then. *B*, Fig. 2, shows the work of *sphaeroma* in palmetto, which is usually considered to resist the attack of the borers. *C*, Fig. 2, shows attack in a specimen of pine. These pictures show quite clearly the difference in the appearance of wood attacked by *sphaeroma* and shipworms. The most distinguishing feature is the difference in size of the entrance, and the fact that *sphaeroma* rarely bores more than 3/8 or 1/2 inch into the wood.

The damage done by *sphaeroma* has been greatly underestimated. Unlike the other borers described, it works in either fresh or salt water. The St. Johns River at Palatka, Fla., is one hundred miles from the sea, and practically fresh the year around, yet piling was found badly infested and in some cases destroyed. The author has found it working in the St. Johns River at Jacksonville, Fla., and at Mayport, Fla., which is within two miles of the Atlantic Ocean. At the latter place, its ravages were of more consequence than those of the shipworm and *liminoria* combined. It was also found to be very numerous at Brunswick, Ga., Charleston, S. C., and at Tampa, Fla. It has previously been reported in a bayou near Slidell, La., and it seems reasonable that this borer may be present along the entire coast line from New Orleans to Charleston, S. C.

All the borers work from the high tide level to many feet below the surface. The damage is most evident between the high and low tide levels because of the action of the waves in breaking away the wood. Typical illustrations of the work of the various borers are shown in Figs. 7, 8 and 9. Fig. 7 shows a longleaf pine pile destroyed at Brunswick, Ga., by *liminoria*. Fig. 8 was taken at Pensacola, Fla., and shows a pine pile destroyed by *xylotrya*. Fig. 9 is of a pine pile at Mayport, Fla., destroyed by *sphaeroma*. It is evident that the destruction of this pile might easily have been mistaken for that caused by shipworms. No illustration is available of a pile destroyed by *chelura*. At *B*, Fig. 2, is shown a specimen of palmetto from the St. Johns River at Mayport, Fla., attacked by *sphaeroma*. This species is generally considered to be immune from attack by borers.

Exact knowledge of the range and extent of the activity of *chelura* and *sphaeroma* is lacking. It would aid in the advancement of science, therefore, if those readers who have an opportunity to observe the destruction of timber by marine wood borers would report the presence of these two borers, wherever found, to the Forest Products Laboratory, Madison, Wis., sending samples of the borers for proper identification.

Electric Ignition Devices for Gas Engines

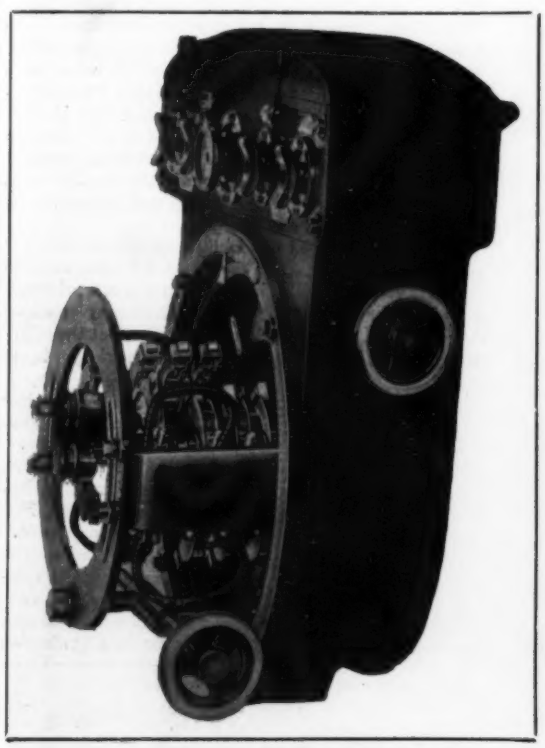
We illustrate an electric device of a recent European design which is now applied very successfully for the ignition of large gas engines. The object of the apparatus, which is quite an elaborate one, though of reliable working, is to produce a quick break at the spark plug inside the engine so as to give the electric arc or spark such as the ignition of the gas requires. At the outside and upon the engine is a device for closing an electric circuit, and when this is done, the spark break is caused to occur under the best conditions so as to cause explosion of the gas. The first part of the apparatus consists of an upright box mounted upon the end of the cam shaft as is seen in the main view, while a second photograph shows some of the details. This device secures the opening and closing of the electric circuits for each of the spark plugs. On the cam shaft is mounted a rotary contact piece, and upon it work the sets of brushes seen in the illustration. Various switching devices are lodged in the top part of the box. Brushes are mounted in a brush-holder somewhat as in a dynamo, and the hand-wheel seen below allows of shifting the brushes so as to regulate the moment of ignition. Besides this, the brushes can be each somewhat altered in position with reference to the others as to make any desired adjustment of the moment of ignition in the rear chamber in relation with the front chamber. Another small wheel at the side of the box regulates the duration of the electric contact, as this is required in engines which run at variable speed; for instance the large gas engines used with blast furnace blowing machines. The second apparatus is the striker which works against the lever of the spark plug. Two of these devices can be seen in the openings of the cylinder casing of the gas engine; and a detail view is also given. At the spark plug inside the engine is a fixed contact against which works a movable electric contact mounted on a rod which passes outside, and is adapted to be worked by a striker, this latter hitting a short lever on the end of the rod so as to cause the break of current at the spark plug. The device here shown consists of a magnet core or armature working on a pivot and carrying a hammer. When the rotary device on the cam shaft closes the electric circuit for the spark plug, the core is attracted by the magnet with a sudden movement, and the hammer strikes the spark plug lever and breaks contact, thus making the arc or spark for the ignition. When the spark ceases the current is broken, and the apparatus loses its magnetism, so that the hammer comes back to zero by a suitable counterweight. Besides being very reliable in operation, this electrically operated break has the advantage that it will work well upon all tensions of direct current between 65 and 220 volts.

Electrical contact-breaker device.

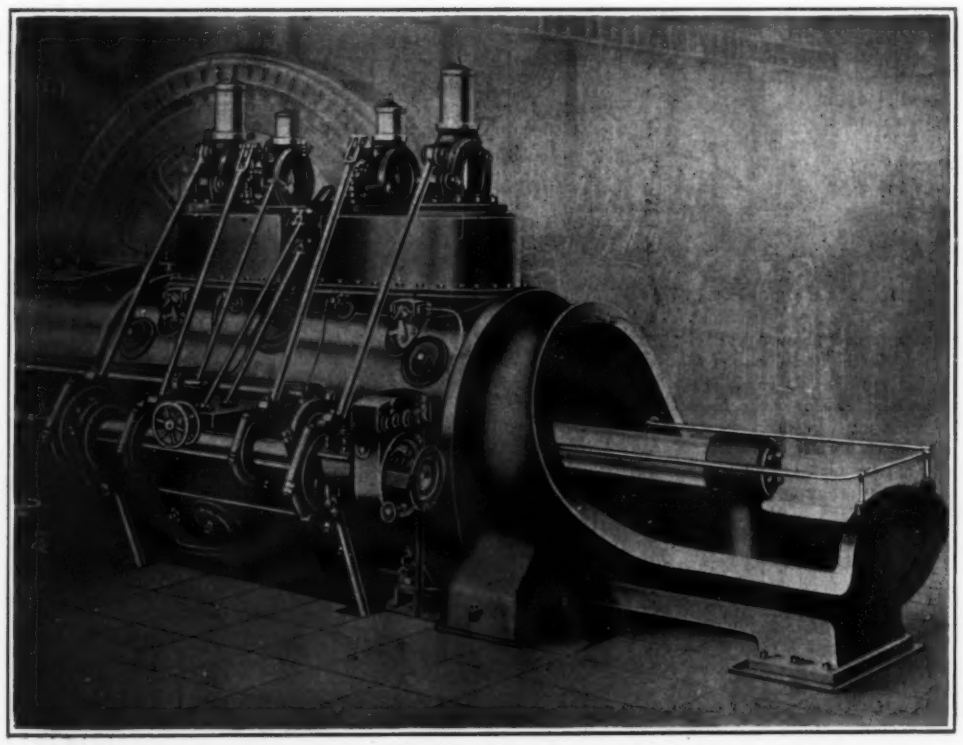
A Museum of Crime

To Prof. Hans Gross of the University of Gratz, Austria, is due the credit of establishing the first museum of criminology and criminalistic laboratory, where the weapons, tools, and other paraphernalia and materials used by criminals are assembled to assist in the analysis of the workings of criminal minds and a study of methods and systems for dealing with this large and dangerous class of every community. This museum was established in 1895-1896, and since then other establishments of the same character have been organized, following the plans which he successfully formulated.

One of the most important of these is the Society of Criminology and Social Defense in Paris, which has a membership of over two hundred, including many prominent representatives of the law, the police and medical profession; and it was organized to concentrate and centralize the scattered efforts of individuals who were studying this disquieting social problem, and to make the results of their work available for mutual information. The valuable and extensive museum collection of the society was presented to it by M. Pechard, a former Superintendent of Police of Paris, and represents the gatherings of a lifetime.



Rotary contact closer on end of camshaft, showing adjustable contact brushes.



Rear cylinder of a large horizontal gas engine, showing electrical ignition apparatus on end of camshaft, and contact breakers in openings of the cylinder casing.

Acoustics of Auditoriums—I*

An Investigation of the Acoustical Properties of the Auditorium of the University of Illinois

By Prof. F. R. Watson

I. Introduction.

Much concern has arisen in late years in the minds of architects because of the faulty acoustics that exist in many auditoriums. The prevalence of echoes and reverberations with the consequent difficulty in hearing and understanding on the part of the auditor defeats the purpose of the auditorium and diminishes its value.

The Auditorium at the University of Illinois presents such a case. The building is shaped nearly like a hemisphere, with several large arches and recesses to break up the regularity of its inner surface. The original plans of the architect were curtailed because of insufficient money appropriated for the construction. The interior of the hall, therefore, was built absolutely plain with almost no breaking up of the large, smooth wall surfaces; and, at first, there were no furnishings except the seats and the cocoa matting in the aisles. The acoustical properties proved to be very unsatisfactory. A reverberation or undue prolongation of the sound existed, and in addition, because of the large size of the room and the form and position of the walls, echoes were set up.

If an observer stood on the platform and clapped his hands, a veritable chaos of sound resulted. Echoes were heard from every direction and reverberations continued for a number of seconds before all was still again. Speakers found their utterances thrown back at them, and auditors all over the house experienced difficulty in understanding what was said. On one occasion the University band played a piece which featured a xylophone solo with accompaniment by the other instruments. It so happened that the leader heard the echo more strongly than the direct sound and beat time with it. Players near the xylophone kept time to the direct sound, while those further away followed the echo. The confusion may well be imagined.

Thus it seems that the Auditorium was doomed to be an acoustical horror; that speakers and singer would avoid it, and that auditors would attend entertainments in it only under protest. But the apparent misfortune was in one way a benefit since it provided an opportunity to study defective acoustics under exceptionally good conditions and led to conclusions that not only allowed the Auditorium to be improved but also indicate some of the pitfalls to be avoided in future construction of other halls.

An investigation of the acoustical properties of the Auditorium was begun in 1908 and has continued for six years. It was decided at the outset not to use "cut and try" methods of cure, but to attack the problem systematically so that general principles could be found, if possible, that would apply not only to the case being investigated but to auditoriums in general. This plan of procedure delayed the solution of the problem, since it became necessary to study the theory of sound and carry out laboratory investigations at the same time that the complex conditions in the Auditorium were being considered. The author spent one year of the six abroad studying the theory of acoustics and inspecting various auditoriums.

The main echoes in the Auditorium were located by means of a new method for tracing the path of sound, the time of reverberation was determined by Sabine's method, and a general diagnosis of the acoustical defects was made. Hangings and curtains were installed in accordance with the results of the study so that finally acoustical properties were improved.

II. Behavior of Sound Waves in a Room.

When a speaker addresses an audience, the sounds he utters proceed in ever widening spherical waves until they strike the boundaries of the room. Here the sound is partly reflected, partly transmitted, and the rest absorbed. The amounts of reflection, absorption and transmission depend on the character of the walls. A hard, smooth wall reflects most of the sound so that but little is transmitted or absorbed. In the case of a porous wall or a yielding wall, the absorption and transmission are greater, and the reflection is less. After striking a number of reflecting surfaces, the energy is used up and the sound dies out.

The reflection of sound produces certain advantages and disadvantages for the acoustics. When it is considered that sound travels about 1,100 feet a second it may be seen that a room of ordinary size is almost immediately filled with sound because of the many reflections. In a room 40 feet square, for instance, the number of reflections per second between opposite walls is 1,100 ÷ 40, or approximately 27. The number is really greater than this, since the sound that goes into the corners is reflected much more frequently than out in the middle where the distances between the walls are greater. The result is that the sound mixes thoroughly in all parts of the room so as to give the same average intensity; that is, the sound is of the same average *loudness* for all auditors, even for those in the remotest corners.

Though the reflection of sound has the advantage of fulfilling the conditions for loudness, it introduces at the same time possibilities for setting up defective acoustics. For instance, when the walls of the room are hard and smooth very little energy is lost at each impact of the sound and many reflections take place before it finally dies out. This slow decadence of the sound, or *reverberation* as it is called, is the most common defect in auditoriums.

If a speaker talks in such a hall the auditors have difficulty in understanding. Each sound, instead of dying out quickly, persists for some time so that the succeeding words blend with their predecessors and set up a mixture of sounds which produces confusion. The cure for the trouble is brought about by the introduction of materials such as carpets, tapestries, and the like, which act as absorbers of sound and reduce the time of reverberation.

When music is played in an auditorium with a prolonged reverberation, the tones following one another blend and produce the same effect as that of a piano

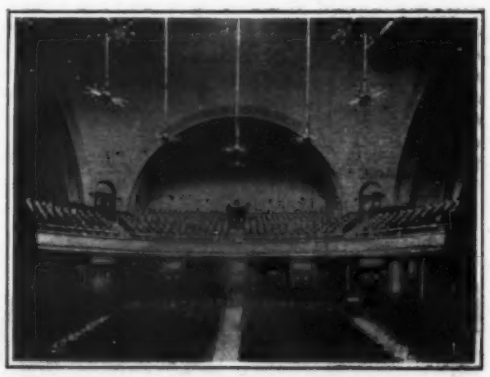


Fig. 1.—Interior view toward balcony.

when played with the loud pedal in use. A reverberation is more advantageous for music than for speech, since the prolongation and blending of the musical tones is desired, but the mixing of the words in a speech is a distinct disadvantage. When curing this defect for halls used for both music and speaking, a middle course must be steered, so that the reverberation is somewhat long for speaking and somewhat short for music, yet fairly satisfactory for both.

Going back to the consideration of the reflection of sound, it is found that another defect may be produced, namely, an *echo*. This is the case when a wall at some distance reflects the sound to the position of the auditor. He hears the sound first from the speaker, then later by reflection from the wall. The time interval between the direct and reflected sound must be great enough to allow two distinct impressions to be made. This time is about 1.15 of a second, but varies with the acuteness of the observer. The farther off the wall is, the greater is the time interval and the more pronounced is the echo. If the wall is not very distant, the time interval is too short to allow two distinct impressions to be made, and the effect on the auditor is then much the same as if his neighbor at his side speaks the words of the discourse in his ear at the same time that he gets them directly from the speaker. In case the reflecting wall is curved so as to focus the sound the echoes are much more pronounced. A curved wall wherever it may be placed in an auditorum is thus always a menace to good acoustics.

There are other actions of the sound that may result in acoustical defects. The phenomena of *resonance*, for instance, may cause trouble. Suppose that the waves of sound impinge on an elastic wall, not too rigid. If these waves are timed right they set the wall in vibration in the same way that the bell ringer causes a bell to ring by a succession of properly timed pulls on the bell rope. The wall of the room will then vibrate under the action of this sound with which it is in tune and will reinforce it. Now suppose a band is playing in a room. Certain tones are reinforced, while the others are not affected. The original sound is then distorted. The action is the same on the voice of the speaker. The sounds he utters are complex and as they reach the walls certain components are reinforced and the quality of the sound is changed. This action of resonance may also be caused by the air in a room. Each room has a definite pitch to which it responds, the smaller the volume of the room the higher being the pitch. A large auditorium would respond to the very low pitch of the bass drum. In small rooms and alcoves the response is made to higher pitched tones, as may be observed by singing the different notes of the scale until a resonance is obtained.

Another action of sound causes the *interference of waves*. Thus the reflected waves may meet the oncoming ones and set up concentrations of sound in certain positions and a dearth of sound in others.

Summing up, it is seen that the effects of sound which may exist in a room are *loudness*, *reverberation*, *echoes*, *resonance*, and *interference*, and that the most common defects are reverberation and echoes. We now turn to the discussion of the methods of the cure.

III. Methods of Improving Faulty Acoustics.

A. Reverberation and its Cure.

Everyone has doubtless observed that the hollow reverberations in an empty house disappear when the house is furnished. So, in an auditorium, the reverberation is lessened when curtains, tapestries, and the like are installed in sufficient numbers. The reason for this action is found when we inquire what ultimately becomes of the sound.

Sound is a form of energy and energy can not be destroyed. When it finally dies out, the sound must be changed to some other form of energy. In the case of the walls of a room, for instance, it has been shown in a preceding paragraph that the sound may be changed into mechanical energy in setting these walls in vibration. Again, some of the sound may pass out through open windows and thus disappear. The rest of the sound, according to Lord Rayleigh, is transformed by friction into heat. Thus[1] a high pitched sound, such as a hiss, before it travels any great distance is killed out by the friction of the air. Lower pitched sounds, on reaching a wall, set up a friction in the process of reflection between the air particles and the wall so that some of the energy is converted into heat.[2] The amount of sound energy thus lost is small if the walls are hard and smooth. The case is much different, however, if the walls are rough and porous, since it appears that the friction in the pores dissipates the sound energy into heat. In this connection, Lamb[3] writes: "In a sufficiently narrow tube the waves are rapidly stifled, the mechanical energy lost being of course converted into heat. * * * * When a sound wave impinges on a slab which is permeated by a large number of very minute channels, part of the energy is lost, so far as the sound is concerned, by dissipation within these channels in the way just explained. The interstices in hangings and carpets act in a similar manner, and it is to this cause that the effect of such appliances in deadening echoes in a room is to be ascribed, a certain proportion of the energy being lost at each reflection. It is to be observed that it is only through the action of true dissipative forces, such as viscosity and thermal conduction, that sound can die out in an enclosed space, no mere modifications of the waves by irregularities being of any avail."

It should be pointed out in this connection that any mechanical breaking up of the sound by relief work on the walls or by obstacles in the room will not primarily diminish the energy of the sound. These may break up the regular reflection and eliminate echoes, but the sound energy as such disappears only when the friction is set up.

The following quotation from Rayleigh[4] emphasizes these conclusions: "In large spaces, bounded by non-porous walls, roof, and floor, and with few windows, a prolonged resonance seems inevitable. The mitigating influence of thick carpets in such cases is well known. The application of similar material to the walls and roof appears to offer the best chance of further improvement."

Experimental Work on Cure of Reverberation.—The most important experimental work in applying this principle of the absorbing power of carpets, curtains, etc., has been done by Professor Wallace C. Sabine of Harvard University.[5] In a set of interesting experiments lasting

* Abstract of Bulletin 73, of the Engineering Experiment Station. Published by the University of Illinois.

[1] "Theory of Sound," Vol. II, p. 316.

[2] "Theory of Sound," Vol. II, p. 351.

[3] "Dynamical Theory of Sound," p. 196.

[4] "Theory of Sound," p. 333.

[5] "Architectural Acoustics." A series of articles in the Engineering record, 1900; also the American Architect, 1900.

over a period of four years, he was able to deduce a general relation between t, the time of reverberation, V, the volume of the room, and a the absorbing power of the different materials present. Thus:

$$t=0.164\,v\div a \qquad (1)$$

For good acoustical conditions, that is, for a short time of reverberation, the volume V should be small and the absorbing materials, represented by a, large. This is the case in the small room with plenty of curtains and rugs and furniture. If, however, the volume of the room is great, as in the case of an auditorium, and the amount of absorbing materials small, a troublesome reverberation will result.

Professor Sabine determined the absorbing powers of a number of different materials. Calling an open window a perfect absorber of sound, the results obtained may be written approximately as follows:

One square meter of open window space	1.000
One square meter of glass, plaster, or brick.....	.025
One square meter of heavy rugs, curtains, etc....	.25
One square meter of hair felt, 1 inch thick ..	.75
One square meter of audience.....	.96

These values, together with the formula, allow a calculation to be made in advance of construction for the time of reverberation. This pioneer work cleared the subject of architectural acoustics from the fog of mystery that hung over it and allowed the essential principles to be seen in the light of scientific experiment.

In a latter investigation[6] Sabine showed that the reverberation depended also on the pitch of sound. As a concrete example, the high notes of a violin might be less reverberant with a large audience than the lower tones of the bass viol, although both might have the same reverberation in the room with no audience. Again, the voice of a man with notes of low pitch might give satisfactory results in an auditorium while the voice of a woman with higher pitched notes would be unsatisfactory.

These considerations show that the acoustics in an auditorium vary with other factors than the volume of the room and the amount of absorbing material present. The audience may be large or small, the speaker's voice high or low, the entertainment a musical number or an address. The best arrangement for good acoustics is then a compromise where the average conditions are satisfied. The solution offered by Professor Sabine is such an average one, and has proved satisfactory in practice.

The problem of architectural acoustics has been attacked experimentally by other workers. Stewart[7] proposed a cure for the poor acoustical conditions in the Sibley Auditorium at Cornell University. His experiments confirmed the work of Sabine. Marage[8], after investigating the properties of six halls in Paris, approved Sabines's results and advocated a time of reverberation of from ½ to 1 second for the case of speech.

Formulae for Reverberation of Sound in a Room.—On the theoretical side, Sabine's formula has been developed by Franklin[9], who obtained the relation $t=0.1625V+a$, an interesting confirmation, since Sabine's experimental value for the constant was 0.164.

A later development has been given by Jäger[10], who assumes for a room whose dimensions are not greater than about 60 feet, that the sound, after filling the room, passes equally in all directions through any point, and that the average energy is the same in different parts of the room. By using the theory of probability and considering that a beam of sound in any direction may be likened to a particle with a definite velocity, he was able to deduce Sabine's formula and write down the factors that enter into the constants. Applying his results to the case of reflection of sound from a wall, he showed that sound would be reflected in greater volume when the mass of the wall was increased and the pitch of sound made higher. He showed also that when sound impinges on a porous wall, more energy is absorbed when the pitch of the sound is high than when it is low, since the vibrations of the air are more frequent, and more friction is introduced in the interstices of the material.

B. ECHOES AND THEIR REMEDY.

An echo is set up by a reflecting wall. If an observer stands some distance from the front of a cliff and claps his hands, or shouts, he finds that the sound is returned to him from the cliff as an echo. So, in an auditorium, an auditor near the speaker gets the sound first directly from the speaker, then, an instant later, a strong repetition of the sound by reflection from a distant wall. This echo is more pronounced if the wall is curved and the auditor is at the point where the sound is focussed.

To cure such an echo, two methods may be considered. One method consists in changing the form of the wall so that the reflected sound no longer sets up the echo. That is, either change the angle of the wall, so that the reflected sound is sent in a new direction where it may be absorbed or where it may reinforce the direct sound without producing any echoes, or else modify the surface of the wall by relief work or by panels of absorbing material, so that the strong reflected wave is broken up and the sound is scattered. The second method is to make the reflecting wall a "perfect" absorber, so that the incident sound is swallowed up and little or none reflected. These methods have been designated as "surgical" and "medicinal" respectively. Each method has its disadvantages. Changing the form of the wall in an auditorium is likely to do violence to the architectural design. On the other hand, there are no perfect absorbers, except open windows, and these can seldom be applied. The cure in each case is, then, a matter of study of the special conditions of the auditorium. Usually a combination of the surgical and the medicinal cures is adopted. For instance, coffering a wall so that panels of absorbing material may be introduced has been found to work well in bettering the acoustics, and also, in many cases, it fits in with the architectural features.

C. POPULAR CONCEPTION OF CURVES.—USE OF WIRES AND SOUNDING BOARDS.

A few words should be written concerning the popular notion that wires and sounding boards are effective in curing faulty acoustics. Experiments and observations show that the wires are of practically no benefit, and sounding boards can be used only in special cases. Wires stretched in a room scarcely affect the sound, since they present too small a surface to disturb the waves. They have much the same effect on sound waves that a fish line in the water has on water waves. The idea has, perhaps, grown into prominence because of the action of a piano in responding to the notes of a singer. The piano has every advantage over a wire in an auditorium. It has a larger number of strings tuned to different pitches so that it responds to any note sung. It also has a sounding board that reinforces strongly the sound of the strings. Finally, the singer is usually near the piano. The wire in the auditorium responds to only one tone of the many likely to be present, it has no sounding board, and the singer is some distance away. But little effect, therefore, is to be expected.

The author has visited a number of halls where wires have been installed, and has yet to find a case where pronounced improvement has resulted.[11] Sabine[12] cites a case where five miles of wire were stretched in a hall without helping the acoustical conditions. It is curious that so erroneous a conception has grown up in the public mind with so little experimental basis to support it.

Sounding Boards.—Sounding boards or, more properly, reflecting boards, have value in special cases. Some experiments are described later when pronounced effects were obtained. The sounding board should be of special design to fit the conditions under which it is to be used.

Modeling New Auditoriums after Old Ones with Good Acoustics.—Another suggestion often made is for architects to model auditoriums after those already built that have good acoustical properties. It does not follow that halls so modeled will be successful, since the materials used in construction are not the same year after year. For instance, a few years ago it was the usual custom to put lime plaster on wooden lath; now it is frequently the practice to put gypsum plaster on metal lath, which forms an entirley different kind of a surface. This latter arrangement makes hard, non-porous walls which absorb but little sound, and thus aggravate the reverberation. Further, a new hall usually is changed somewhat in form from the old one, to suit the ideas of the architect, and it is very likely that the changes will affect the acoustics.

D. THE EFFECT OF THE VENTILATION SYSTEM ON THE ACOUSTICS.

At first thought it might seem that the ventilation system in a room would affect the acoustical properties. The air is the medium that transmits sound. It has been shown that the wind has an action in changing the direction of propagation of sound.[13] Sound is also reflected and refracted at the boundary of gases that differ in density and temperature.[14] It is found, however, that the effect of the usual ventilation currents on the acoustics in an auditorium is small. The temperature difference between the heated current and the air in the room is not great enough to affect the sound appreciably, and the motion of the current is too slow and over too short a distance to change the action of the sound to any marked extent.[15]

Under special circumstances, the heating and ventilating systems may prove disadvantageous.[15] A hot stove or a current of hot air in the center of the room will seriously disturb the action of sound. Any irregularity in the air currents so that sheets of cold and heated air fluctuate about the room will also modify the regular action of the sound and produce confusion. The object to be striven for is to keep the air in the room as homogeneous and steady as possible. Hot stoves, radiators, and currents of heated air should be kept near the walls and out of the center of the room. It is of some small advantage to have the ventilation current go in the same direction that the sound is to go, since a wind tends to carry the sound with it.

(To be concluded.)

The Widening Pellagra Zone*

THE recent studies of pellagra, and exhaustive reports such as that of the Thompson-McFadden Pellagra Commission, have undoubtedly resulted in the discovery of many obscure cases of this disease which otherwise would have escaped detection. This statement probably applies to a greater extent in the regions that are supposed to be outside the focal pellagra zones than in places where the disease is of common occurrence. Nevertheless, the number of cases that have been reported at points remote from the focal centers, and the fact that many of the conditions attending these cases do not conform to the observations made in the South, force the conclusion that the disease is not only increasing its territory, but is invading classes that have hitherto remained practically immune.

It is possible, of course, that even in remote districts, where pellagra seems only recently to have made its appearance, the disease is not really such a novelty, but simply that it has not been recognized heretofore. This is a reasonable supposition, particularly as regards the milder or abortive type of cases. But it can hardly be true of the virulent types. And the natural conclusion is, since well-marked cases are now making their appearance in districts that seem to have escaped hitherto, that the disease is extending its zone of operation.

The report of the Thompson-McFadden Commission indicates that the disease is usually the concomitant of malnutrition, poverty, and bad hygiene. "In our opinion," says this report, "the view that pellagra is an intestinal infection, transmitted by contaminated food, to which the individual is rendered more susceptible by malnutrition, poorly selected or poorly prepared food and by the common gastro-intestinal disturbances resulting from errors in diet, is a conception worthy of further study."

In most of the cases of this disease that have come under our observation recently the conditions referred to in this report did not prevail, although all of them presented the typical picture of pellagra itself.

According to the Thompson-McFadden Commission observers the disease is peculiarly prevalent among women between the ages of nineteen and forty-five, whereas the rate of prevalence among males drops very appreciably at this time of life. The exact amount of this decline is shown by the fact that, although the rate of prevalence is practically equal in the two sexes among children under ten and among adults over forty-five years of age, in the intervening period the proportion of women afflicted is about four to one.

But perhaps the most interesting single feature presented by the cases brought to our attention in this vicinity, is the fact that they occurred among a class of persons representing a very different economic status from the majority of cases observed by the Thompson-McFadden Commission. And the reports of cases in Los Angeles seem to indicate that the patients were largely those from the better walks of life, or at least were persons accustomed to good food and hygienic surroundings of the middle classes.

Certainly the economic condition of these cases contrasts strikingly with those reported by the Thompson-McFadden Commission observers. For these observers report that 85 per cent of cases occurred among people of insufficient means, who were eating poor, badly prepared food, and where general economic conditions were bad. Probably their findings are distinctly influenced by the relatively high percentage of poverty in the regions under investigation. But in any event it is interesting and significant that the cases seen in Southern California taken collectively refute the old idea that pellagra is largely a "filth disease." Or at least they show that, if the disease was formerly only the accompaniment of poverty, affecting the lower classes, it is now extending its attacks to the more favored strata of society.

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[15] Sabine and Watson. Ibid.

* From the *Medical Record*.

Men's recreation grounds at the Cadbury Works, Bournville, England.

Lawn tennis grounds at Port Sunlight, England.

The Welfare of Workmen in European Enterprises

Improved Housing Provided, and Health and Social Conditions Considered

By C. Van Langendonck

In these days of great competition, especially in the engineering and other allied trades, many firms are alive to the necessity of up-to-date plants; comparatively few of them, however, realize the extent to which the workman's environment affects him and his work.

Experience has, however, proved that frequently a large measure of the success of an enterprise is due to the conditions under which the employees do their work, and the companies who have spent time and money in improving the environment of their workpeople have almost invariably obtained good results.

The justification for securing the welfare of the employee is twofold: First there is the moral obligation of the employer to provide conditions of work that tend to the comfort, moral welfare and self respect of the employed. Secondly, there is the advantage of promoting a cordial attitude on the part of the workmen toward the employer.

We know that great progress in welfare work has been made in American factories. The present article refers only to what the old world has done for insuring a convenient life and agreeable surroundings for their people.

For the sake of convenience, we will group the various features of work under the heads of Health, Recreation and Education, and Housing:

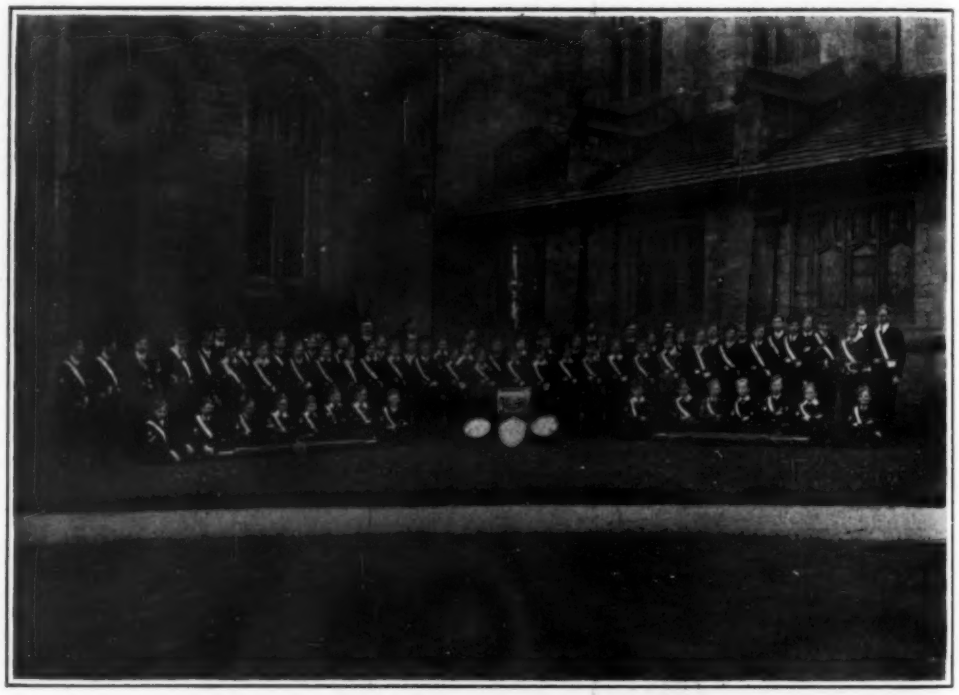
Health.—Under this head, which is the first that should concern the employer of labor, there are two distinct fields for operation: that of the preserving of the workers' health, and that of dealing with their various ailments.

Convenience for the supply of meals for workers living at a distance, the supply of fresh and good fruit at cheap rates, the reduction of the working hours to the lowest possible limit, readily suggest themselves. In addition to lofty and spacious rooms, various contrivances may be introduced for securing abundance of pure air.

It is an undisputed fact that the workman's health is greatly affected by his surroundings, and this, it must be borne in mind, does not end with the present working generation, but must have an influence upon the children who, in time to come, will have to take their fathers' places.

Many European employers have made provision for giving their people opportunity for decently eating a lunch in special factory rooms or restaurants. In most cases arrangements are made for selling at very low prices, good hot coffee or other soft drinks and warm food. Other installations make it possible to warm food brought from home. In the case of married men, for instance, some employers offer the food below cost and think themselves recompensed in other ways. The distribution of prepared food presents no special difficulties, and our photographs show how this is done in the works of Messrs. Cadbury Bros., Bournville (England), and Messrs. Lever Bros. Several large works have their own doctor whose whole time is at the service of the employees.

In many instances lavatories, lockers, dressing and other decent sanitary and toilet conveniences are pro-



Boys' brigade and bugle bands at the works of Messrs. Lever Brothers, at Port Sunlight, England.

Girls' dining room, Port Sunlight, England.

Gymnasium at Bournville, England.

The ambulance brigade at Port Sunlight.

Girls' recreation grounds at Bournville.

vided. No one will dispute that a workman has a right to go home with clean clothes as well as clean face and hands. Further, it is recognized that the number of deaths caused by diseases and illnesses is at least as important a question as that of deaths due to accidents; and in providing comfortable washing and changing accomodation, many lives are spared every year. In numerous works provision is made to deal quickly and efficiently with any cases of sickness which might occur. There are ambulance boxes in different parts of the works, fitted up with the necessary appliances and clear instructions for use.

Recreation.—Much coming under this division deserves a place under the previous one, since the inducements to engage in physical exercises and health-giving games tend to maintain a high standard of health. Experience has demonstrated that the workpeople are showing much enthusiasm for recreation institutions and love to take their recreation in common. Several large European works have their own flourishing recreation clubs. Worthy of notice among others, are the extensive recreation grounds adjoining the works of Messrs. Cadbury: one for women and one for men. These grounds, each of about 12 acres, are laid out to meet the modern requirements of cricket, football, hockey, and other games. It may be said that the development of these sporting games is a powerful factor in the bringing together of the classes. Once in football costume, for instance, the distinction of proletarian and millionaire, workman and foreman, no longer exists.

Chiefly in England, magnificent baths are found annexed to the works. The managing staff have felt that with opportunities for regular weekly bathing and learning to swim, the working people would not only be stronger and healthier, but personal hygiene would be kept to a higher standard.

Education.—One of the most important means of social uplifting is the institution of youths' clubs. If the social and educational welfare of the young generation received a more careful superintendence, it is certain many of the social problems, which at present press for solution, would no longer arise. None need the attention of the welfare worker more than the generation in which the hope of the future is centered, and no institution will have more to show for its existence, both in the present and the future, than these clubs whose members, it may be presumed, will some day be holding positions of responsibility with the firms who employ them. These club-houses generally contain reading rooms, library, bagatelle room, class room, cooking school for young women, museums, etc.

A serious feature of welfare work, and one which it is expected many employers of labor will take up in the future, is the offer made by firms to pay a portion of the evening technical education fees of the younger employees. In several instances, classes are also held directly in connection with the works. In various works encouragement is given to employees to make suggestions for the increased comfort of the workpeople, or for any improvements in the methods adapted for dealing with the work; and cash prizes are awarded for such suggestions as meet with approval.

General.—In many instances all employees of the same enterprise are members of a general sick club in the works and are thus sure of a regular allowance when ill. Often special sections provide for the payment of a weekly sum to any members who are by rule bound to leave the works when an outbreak of infectious disease takes place in their homes. Numerous works have their own hospital, where the services are quite gratuitous.

Mention should be made of the savings funds, where the employees may deposit money, receiving interest averaging between 4 and 5 per cent per annum; and the pension schemes, the funds of which are provided partly by the companies and partly by weekly or monthly deductions from the wages of the subscribers. In several cases committees, including representatives of the workpeople, are appointed to relieve the directorate of the matters affecting the funds.

Housing Problem.—Of prime importance is the housing problem. Too often the working people are compelled to live under conditions which are a scandal to our civilization. These are housed in close, dirty, evil-smelling lanes and courts, deprived of fresh air and sunshine; strangers to the sight of grass and flowers and trees, and without opportunity for healthy recreation. All this inevitably tends to produce moral and physical deterioration.

Several important European firms have made a most successful study of this problem, and some of our illustrations give views of the really beautiful homes provided.

On entering these workmen's villages, the visitor is charmed by its beauty and perfect harmony. Generally the houses are built in groups, with three to nine houses in each group at most, and there are no two groups alike. The roads are very wide, and trees, verdure and small parks are to be seen in every direction. The majority of the houses have two sitting rooms, a kitchen or scullery, three bedrooms, and the usual conveniences. There are others with one large living room instead of two smaller ones, and a few with only two bedrooms.

Every house has its garden, and, in addition, every inhabitant can have a nearby allotment garden to cultivate. As a rule the tenants take a keen interest in their gardens, and cultivate them with great success.

The beautiful and substantially-built cottages with their low rentals, the trimly-kept lawns and gardens, the facilities generally offered for the free education of the children; the fact that, as a rule, the sale, distribution or consumption of intoxicating liquor is suppressed, show at first glance that the conditions under which the inhabitants of these communities live are far superior to those enjoyed by the great majority of the workpeople.

Modern Electric Protective Devices

In the modern electric generating station the protective devices represent the highest class of design and workmanship in the entire installation, while the cost of the switchboard frequently nearly equals that of the plant controlled by it. In the old days, however, says J. Gardner, writing in *Vulcan*, few or no protective devices were installed. For instance, in a power station still running there are several 2,000-volt 300-kilowatt single-phase generators controlled by open single-pole switches of the simplest type and without even a fuse in circuit; one side of the system is earthed. Everything operates quite satisfactorily until a cable goes to earth or someone makes a mistake; then there is a serious accident. A case of this kind recently occurred. A direct-current generator coupled to a steam engine was being run up in readiness for paralleling with other machines. When the volts were about one hundred the attendant closed the main switch of this machine by mistake. Although the fault was discovered immediately, the rush of current into the machine pulled the armature winding partly round the core, and some of the commutator segments were nearly forced out of the "V" rings. The driving pins in the armature were sheared off and the insulation of the core was damaged. The armature had to be entirely re-wound and the commutator rebuilt.

Cottages at Port Sunlight, England.

A dinner hour scene—cricket is popular with the girls.

Rail Sections as An Element in Steam and Electric Traction—I*

Early History of Track Construction and Developments Made Possible

By P. H. Dudley, C.E., Ph.D., Consulting Engineer, New York Central Lines, New York

THE 6-inch 100-pound steel rail section, laid first in 1892 on the New York Central & Hudson River Railroad, was designed with a broad thin head for an ample bearing surface of the wheel treads on a stiff rail, which could distribute a large portion of their loads to the wheel spacing for a smooth riding track. The fact is not generally appreciated that the wheel load spacing of the equipment controls the spans of the bending rails on the flexible crossties in the ballast, rather than their spacing under the rail. It was, as a rail section of that date, the most efficient engineering structure in use in the world and has fulfilled its complex functions with safety, precision, and economy as an essential element of the means of railway transport. (See Fig. 8.)

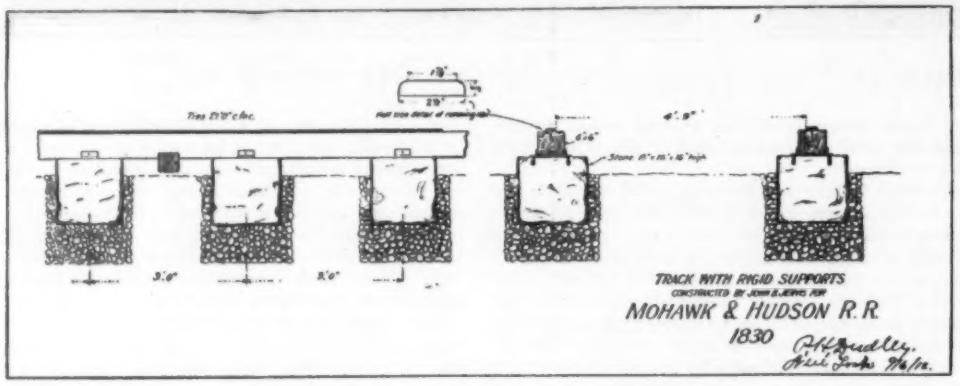


Fig. 1.

The modern steel trains, the Empire State Express, the Twentieth Century Limited and others, each have a kinetic energy greater than the heaviest projectile of any high power guns yet fabricated. The stored energy for the speed of the train can be absorbed and rendered inert through several wheel contacts on the rails, when the engineer touches the handle of the air brakes to stop his train. The artillerist concentrates the stored energy of a projectile upon a single contact for destructive effect, while the railway engineer carries and distributes the total load of a train on many wheels, and therefore absorbs the stored energy for the speed of the train through several contacts on the rails for safety and utility. The weight of the rails on their flexible crosstie supports in the ballast and subgrade, occupied by the length of the steam railway or multiple unit train on its several wheels, may be but one-hundredth of the load which the rails can carry when subdivided, distributed, and constrained through several wheel contacts. A rail of suitable stiffness on the flexible crossties in the ballast, due to the principle or efficiently subdivided, distributed and constrained loads, is better for good track, smooth riding of the equipment, and economical operation, than that of the major part of the wheel loads concentrated on each crosstie, through a weak rail section.

The 6-inch 100-pound section is a model of efficiency through its metal to limit and distribute the reduced strains of its wheel loads to the crosstie supports, for it can withstand thousands of repetitions with marvelous exactness for similar conditions of service without failure.

SOME INTERESTING HISTORIC DEVELOPMENTS IN TRANSPORTATION.

Schenectady being in the valley of least resistance to travel from east to west and *vice versa*, inherited the Indian trail and canoe, then developed transportation, by (1) the Conestoga wagon, (2) the stage coach, (3) the canal, (4) steam railroads, (5) electric traction.

The Mohawk & Hudson Railroad from Schenectady to Albany was chartered in 1826, although active work upon its construction did not commence until 1830 and 1831 for the Saratoga & Schenectady Railroad. Mr. John B. Jervis was chief engineer of both roads for construction. Locomotives were then in their primitive stage of evolution, of small tractive effort, and able to ascend only moderate gradients of a few feet per mile. Mr. Jervis was therefore obliged to construct for the Mohawk & Hudson Railroad an inclined plane operated by a stationary engine, for the ascent and descent of the cars at Schenectady, from the Mohawk River to the plateau on its banks. A similarly inclined plane was constructed from the Hudson River for the Albany terminal. The alinement of the track of the Mohawk & Hudson Railroad for 14 miles on the plateau was composed of three tangents connected by two curves. The one about midway of the line was 396 feet long and of 23,000 feet radius; the second, near Albany, was 594 feet long and of 4,200 feet radius. The head of each inclined plane connected with the tangent at either end by a curve 528 feet long and of 1,100 feet radius. To make the gradients and curves easy for the locomotives, the cuts and fills were heavy, and the cost of the railroad averaged $40,228 per mile, a large sum for 1831, but a small cost for the principles elucidated.

The New York Central & Hudson River Railroad now occupies the original line from Carmen to Karner, and includes the curve of 23,000 feet radius. The total length of the railroad at first was 15.86 miles, and it did not run into the business portion of the capital; but later a branch line for passengers was permitted in State Street. New York State had just completed its Erie Canal, and the Mohawk & Hudson Railroad Company at first was not allowed to transport freight.

We can study with profit the historic but frail structures of the track, the primitive locomotives and the strap iron rails for the principles of construction which eventually directed their evolution into types in eighty-three years for the present developments. This has required the application of the facts of experience and the principles of science of the preceding ages, on a more extensive scale than ever before in the history of mankind.

The superstructure of the track for the Mohawk & Hudson Railroad on the plateau between the inclined planes at Schenectady and Albany was constructed of a strap iron rail, 2½ inches wide and ⅞ of an inch thick, with the upper corners rounded to 1⅞ inches and spiked in the center of longitudinal stringers 6 by 6 inches, for their strength as a girder, Fig. 1. The author has one of the original rails and a piece of a stringer. To make an expected enduring track of rigid supports in the roadbed, pits 2 feet square and with 3-foot centers were prepared for each line of stringers, and in each pit were placed about nine cubic feet of broken stone which cost $2 per cubic yard. Near Schenectady, to support the stone blocks, the broken stone was placed in two parallel trenches. Some blocks were placed on these foundations, each of 2½ cubic feet, 16 inches in height, with a top surface of 15 by 16 inches, and upon these stringers were laid and attached by knees and spikes to support the strap iron rails. The iron formed the bearing surface for the wheel contacts and the guide for the flanges of the wheels of the passing locomotives and cars, and the stringer as a separate piece supplied the strength as a girder.

Mr. Jervis opened the Mohawk & Hudson Railroad August 9th, 1831, with the locomotive "DeWitt Clinton," which was carried upon two pairs of drivers and weighed 6,758½ pounds, and was intended to be under three gross tons, exclusive of the light four-wheeled tender. The three cars were stage coach bodies with flanged wheels for the track. The length of the entire train was less than that of one of the present Pacific types of locomotives.

A locomotive named the "John Bull" was built by Robert Stephenson & Son, Newcastle-upon-Tyne, and weighed 12,742 pounds and had under the front end a pair of rigid carrying wheels, while the single pair of driving wheels carried 8,745 pounds. The wheels of both locomotives were 4 feet 8 inches in diameter, and the wheel base of each, 4 feet 6 inches. The weight of the "John Bull" was too great for the superstructure, and was not subdivided and distributed by a wheel base sufficient in length to ride steadily over the track, and was seldom used as originally made.

Mr. John B. Jervis was constructing the Saratoga & Schenectady Railroad when he opened the Mohawk & Hudson. Three miles of track were finished with stone blocks set upon broken stone, which carried the stringers, the same as used for the Mohawk & Hudson Railroad. The strap rail was an angle iron spiked on the upper inner corners for the track, to provide for inch flanges on the engine drivers and wheels. Mr. Jervis built the balance of the line with crossties upon which the stringers were placed to support the small angle strap iron rails, and ballasted the track for the flexible superstructure and an elastic roadbed, the principle in use to-day on all steam railroad tracks. The design of the superstructure of the track of the Mohawk & Hudson Railroad on the rigid supports is shown in Fig. 1, and the Saratoga & Schenectady Railroad on elastic supports in Fig. 2, from the best information to date. Fig. 3 shows the original English locomotive "John Bull," by Robert Stephenson & Co., 1831.

Mr. Jervis found the engines were more severe upon the strap iron rails of the Mohawk & Hudson Railroad than was expected, and in 1832 he designed his leading four-wheel truck, arranged for both lateral and vertical flexibility to guide the front of the locomotive in place of the ordinary carrying pair of wheels of the English construction (see Fig. 4). This was also to extend the running gear of the engine, to subdivide and distribute the front truck load on the rail for the following driving wheels. The wheel base of the engine constructed on this important principle was found much easier upon the track and was extensively copied, and in a few years another pair of driving wheels was added for new engines, constituting the American eight-wheel or 4-4-0 type of engine.

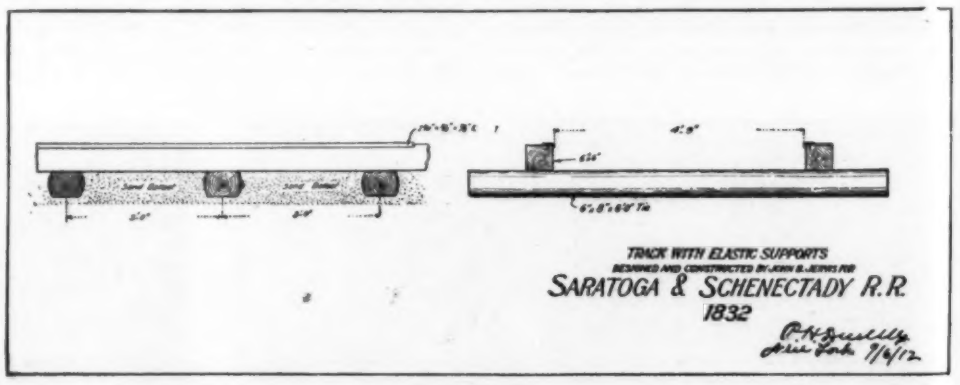


Fig. 2.

The locomotive in evolution had now reached a type capable of enlargement, so flexible in the wheel base as to carry sufficient weight on the driving wheels for adhesion to pass around sharp curves and ascend gradients of 40 feet per mile, and superseded the inclined planes worked by stationary engines, used in the earlier railways.

My tribute to the enduring work of Mr. Jervis on the

* Courtesy of the *General Electric Review*.

Mohawk & Hudson Railroad, for all coming time, is for his adoption and practice of the principle involved in the leading four-wheel truck for flexibility, and extension of the wheel base of the locomotive for subdivided, distributed and constrained wheel loads on the rails, crossties, ballast, and subgrade. The practice of the principle of a flexible superstructure on an elastic roadbed, used on the Saratoga & Schenectady Railroad, is now followed by all steam railways of the world.

IRON TEE RAIL SECTIONS.

Robert Livingston Stevens in 1830 designed for the Camden & Amboy Railroad a section of rail, the principle of which combined in one piece the bearing surface for the wheel treads, the guide for the wheel flanges, and the strength for the girder, with a base to rest upon and be spiked to the crossties. This was the prototype of our present rail sections, and was rolled in 1831 by Guest & Co. of Wales. It did not come into general use on account of the expense for many years, and then the head was made more pear-shaped. The construction of the early railways with iron rails was slow, for at first all the iron used was imported from England or Wales.

There were only 23 miles of railway track in this country in 1830 composed of strap iron rails laid upon wooden or stone stringers, and only increased to 2,818 miles in 1840, as the frail superstructure of the track had not taken suitable form for its development; and strap iron rails were prohibited by law in New York State in 1844. The physical properties of wrought iron were sufficient for the installation of the early railways but inadequate for their development.

BESSEMER'S INVENTION FOR MAKING STEEL.

Bessemer steel replacing iron rails marks a distinct epoch in the construction of mileage, maintenance, and operation of railways. Bessemer's grand conception was the application of the fact that one half of one per cent of carbon combined with iron made a ductile steel of greater physical properties than wrought iron, and as cast iron contained from 3½ to 4 per cent of carbon, 1.25 to 2.5 per cent of silicon, 0.50 to 1 per cent of manganese, 0.03 to 0.06 of phosphorus, a non-ductile and brittle product, he made a suitable converter and blew air through the bath of molten cast iron to burn out, first, the silicon and manganese, then the excess carbon above that desired for his grade of steel. This direct method proved only possible with the nearly pure Swedish irons. It was required in all other countries to select pig iron in which the impurities of phosphorus and sulphur would be 0.1 or under, as required for the grade of steel, and then decarburize the molten bath by blowing air through it and subsequently recarburize the blown metal with the desired carbon, manganese, and silicon contents. This was a success, and, by the large product which could be made, rendered possible the present railway development by the use of steel rails of greater physical properties and more homogeneous product, to replace those of iron of inadequate physical properties.

The use of Bessemer steel rails commenced in this country in 1863, with imported English brands of 500 to 1,000 tons for trial. The early rails cost $100 to $120 gold per ton, which, with the premium, made the cost from $240 to $260 in currency during the civil war. The early Bessemer steel rail sections were from 3½ to 4¼ inches high, and the weights ranged from 56 to 60 pounds per yard.

The engineers of the New York Central & Hudson River Railroad made deflection tests and in 1870 increased the height of the rails to 4½ inches, and the weight of the section from 60 to 65 pounds per yard. Large tonnages of the 65-pound section were rolled in England and France, and the third and fourth tracks were laid with it about 1870 and 1871, and cost from $100 to $110 per ton. These early steel rails were so expensive that the weights of the sections were rolled as light as was considered safe for service. They were not stiff, and had small mechanical properties, and deflected to a marked extent under the wheels, and transmitted concentrated instead of distributed loads to each crosstie. A committee of the American Society of Civil Engineers, in 1873, studying the small wear of the rail under the light wheel loads, came to the conclusion that it would be desirable to design for economical reasons what was termed a residual section, and then add sufficient metal to the top of the head for several years' wear (see Fig. 5). They modified entirely the type of the section, reduced the percentage of the metal in the base and used more in the deep head, providing, as they supposed, for many more years' duration. The question of a section as an engineering structure for stiffness to reduce the train resistance and maintenance was not considered, as it was in advance of the ideas of the evolution of rail sections at that date.

The deep, heavy head, and the change from the thick to the thin base, did not make as safe a girder for heavy traffic, nor result in an equal quality of metal in the rail, as had been secured in the shallow head and thick base of the early sections, to which type we are now reverting from experience, for superior girders. The light steel rails, however, enabled the railway companies to save the cost of renewing the iron rails so often, and lessened the operating expenses, though it

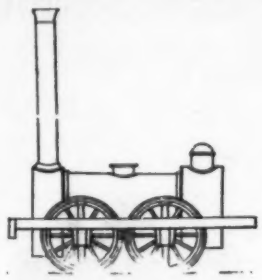


Fig. 3.—"John Bull" locomotive on the Hudson and Mohawk Railway, 1831. Built by Robert Stephenson & Son.

did not permit much increase in the wheel loads of the locomotives and cars over those used upon the iron rails. The railway officials were anxious to improve their tracks and increase the wheel loads of the motive power and equipment to run faster and heavier express trains, and also haul larger freight train loads. I made

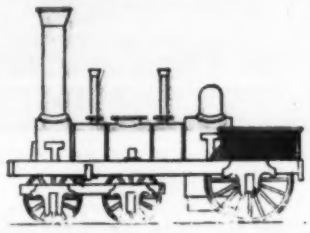


Fig. 4.—First bogie engine, Saratoga and Schenectady Railway. Jervis' four-wheel front truck engine, built by Robert Stephenson & Company, 1833.

a track indicator, with a special six-wheel truck, to measure and record autographically the undulations of the rails in the tracks, to determine what was necessary to improve them in an economical manner.

INSPECTION OF TRACKS WITH TRACK INDICATOR.

I commenced the investigation of the undulation of the rails by my track indicator in 1879. The New York

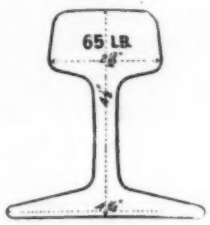


Fig. 5.—New York Central and Hudson River Railroad, 1870.

Central at that time had 4½-inch 65-pound steel rails (see Fig. 5) in general use upon the main lines, and upon some of the subsidiary lines, 56 and 60-pound, and the height was from 4 to 4½ inches. The Boston & Albany had a 4½-inch 72-pound, and the Pennsylvania, two sections of 4½-inch 67-pound.

The diagrams taken from over 10,000 miles of the

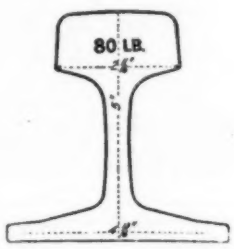


Fig. 6.—New York Central and Hudson River Railroad, 1884.

Eastern lines demonstrated the fact that the rails did not have sufficient mechanical properties to distribute the loads in the wheel spacing to any marked extent, as each crosstie received nearly the major percentage of the wheel effects. The crossties cut under the rail seats with rapidity, which permitted the light equipment to cause destructive, expensive and useless injury, while the train resistance was high, as well as the cost of maintenance and operation. I added a mechanism in 1881 to sum up the undulations into feet and inches, shown on the large diagrams, of 1 inch in length of paper to 50 feet of track, from which the amount per mile and section was secured for tabulation, and afforded definite measures of what labor could do and what could be expected from stiff rails in the track.

The investigations by my track indicator showed on all of the lines that the rails had taken definite forms in the track, which I classified under three distinct types: First, second, and third forms of permanent set.

First form: Rails which were low at the joints and high in the center.

Second form: Rails low in the joints and center, but high in the quarters.

Third form: Rails more or less wavy on the surface, due to conditions of manufacture.

There were combinations of the first and second, and the second and third upon a few rails.

The forms of permanent set also indicated that the rails were not sufficiently stiff so the track could be maintained in good condition for any length of time without constant attention to surfacing by the trackmen, and the results of their labor did not become cumulative from year to year. The rails began to take a set after one or two years cutting out at the joints under the passing wheel loads, the unit fiber strains being higher than in the present stiffer sections. It was evident that the section should have sufficient metal for its elasticity to carry the wheel loads before the permanent set occurred.

I designed the pioneer 5-inch, 80-pound steel rail for the New York Central in 1883 (Fig. 6), to furnish the superintendents of motive power and the engineers of maintenance of way a better steel rail section as an engineering structure than ever before used. It was, as a girder, 66 per cent stiffer than the 4½-inch, 65-pound section of the New York Central & Hudson River Railroad, secured by the addition of only 15 pounds or 23 per cent more metal per yard, and an increase of ½ inch in height for the section. The rail was rolled in April, 1884, and laid in July of the same year, on the four tracks from Grand Central Station to Harlem Junction, 5½ miles. The demonstration of its value in stiffness was a satisfaction to railway officials, and soon was followed by a 5-inch, 80-pound section for the Michigan Central Railway, and a 5-inch, 85-pound section for the Pennsylvania Railroad. The value of stiffness in rails as girders was so obvious that in 1883, after I had designed the 5-inch 80-pound section already mentioned, and before it was rolled, I stated, upon the Boston & Albany diagrams for the year 1883, that it would be possible for them with new stiff rails on a well ballasted roadbed to reduce the undulations of the track to between the fifteenth and sixteenth line upon my condensed diagrams.

I distributed the area of metal for the head, web, and base of the Boston & Albany 95-pound section, which was limited to 5 1/32 inches in height by the railway company owing to the curvature and heavy gradients of the line. I commenced to roll the rail in 1891, and the entire line of 200 miles of double track from Boston to Albany was completed in the summer of 1897. My inspection of the track in the autumn showed the average undulation for the entire track was 15 42/100 lines per mile upon my condensed diagrams, and confirmed the estimate of 1883, fourteen years in advance of its consummation.

(*To be concluded.*)

Deep Sea Soundings

THE methods of taking deep sea soundings heretofore employed have involved a number of sources of error, the principal one being the form assumed under water by the line, which is calculated to cause an error of at least one thirtieth of the indicated depth, under the most favorable conditions. To eliminate this error completely A. Berget describes in *Comptes Rendus* a piezometer which he has constructed. Water is adopted for the compressible fluid, since its compressibility is practically constant and its sensitiveness uniform at all depths. The instrument consists of a reservoir filled with water, whose base terminates in a long tube of ½ millimeter internal diameter which communicates with a side vessel full of mercury and open for reception of the pressure. The tube is silvered internally and graduated externally. The whole apparatus is 25 centimeters long. As the apparatus descends, the mercury is forced up the small tube and dissolves away the silver, thereby denoting the amount of compression, and hence the depth attained. The apparatus was first graduated experimentally by means of a hydraulic press. A thermometer is attached to the side of the piezometer to allow a correction for thermal dilatation. The sensitiveness of the apparatus may be increased to any extent by enlarging the volume of the water reservoir, and diminishing the cross-section of the graduated tube.

Measuring Shocks of Vehicles and Vibrations of Buildings*

A Means for Investigating Important Traffic Problems

THE traffic problem in great cities is continually growing more difficult. It is necessary to take into consideration the conflicting interests of the vehicles, the highways, and the owners of abutting buildings which are affected by the character of the traffic and the condition of the pavement.

In Paris the difficulty is greatly increased by the nature of the soil, which is undermined by subways, sewers, and catacombs. When we consider the ever-increasing number and weight of automobile vans and trucks, it is not surprising that the vibrations of buildings have become serious enough to justify complaints on the part of their occupants.

When this conflict of interests leads to lawsuits it becomes necessary to determine precisely the nature of the vibrations caused, or sustained, by each of the three elements: the vehicle, the roadway, and the abutting

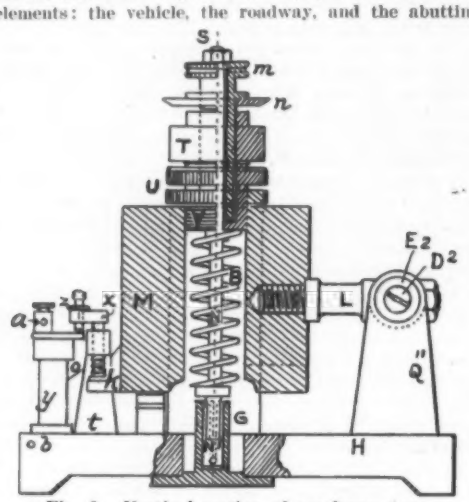


Fig. 2.—Vertical section of accelerometer.

building. For this purpose M. Auclair and I have devised an instrument, the "accelerometer," by which the shocks sustained can be measured.

Other things being equal, the wear or fatigue at any point of a rotating body increases with the rate of variation of velocity at that point. It is this change of velocity, or acceleration, that our instrument is designed to measure.

When the tractive effort applied to a vehicle is suddenly augmented the speed of the vehicle is suddenly

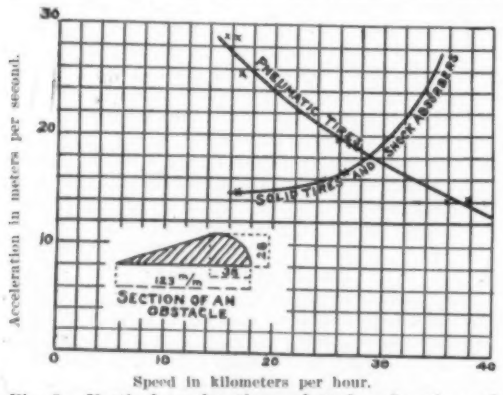


Fig. 5.—Vertical accelerations, plotted as functions of the speed.

increased, by an amount which we will denote by A, and which impresses on any mass M, within the vehicle, a force $M \times A$, which tends to displace that mass in the direction opposite to that of the vehicle's motion. It is this force that compels a standing subway passenger to exert a violent effort to maintain his erect posture when the train starts or stops, and it is precisely the same force that tends to separate the bricks of a building shaken by the passage of a heavy vehicle.

As this destructive force is due to acceleration, the magnitude of the acceleration is the quantity to be determined. Our accelerometer (Fig. 1) furnishes an accurate measure of the acceleration at the point where the instrument is placed. This acceleration, as we shall see, is the measure of the fatigue of the material at that point.

The essential parts of the apparatus are shown in Figs. 2 and 3. L is a T-shaped piece of steel, the shank

By A. Boyer-Guillon in *La Science et la Vie*.

of which is screwed into the side of a bronze cylinder M, weighing about four pounds, and which can turn about the axis of its branches, i. e., the horizontal axis $D_1 D_2$. The bearings are furnished by two pointed screws, $D_1 p_1$ and $D_2 p_2$, which pass through bronze posts $Q Q''$, bolted to the base H. These screws are regulated

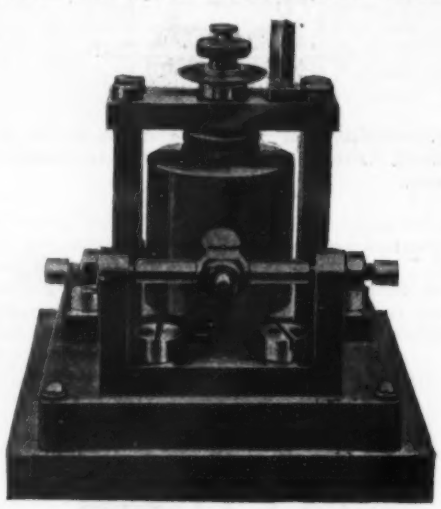


Fig. 1.—The accelerometer of Boyer-Guillon and Auclair.

by means of the nuts $E_1 E_2$. The heavy cylinder M is supported by the spring B which passes through it and is attached at V to the screw bolt U. The lower end of the spring rests on a disk attached to its guide-rod S, which is prevented from turning by the pin N', which passes through the rod and its socket G. The tension of the spring B, which tends to lift the cylinder M and press it against the cross-piece T, is regulated and measured by means of the screw m, the millimeter scale q and the graduated circle of hundredths n, attached to

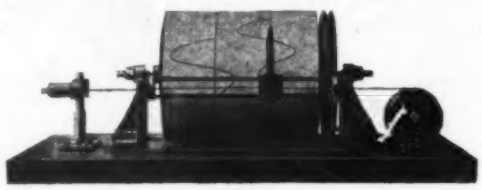


Fig. 4.—The flexion recorder.

the screw. The travel of the cylinder M is regulated by another screw and nut, which comprise the piece U.

The apparatus is completed by an electric contact breaker which indicates the exact moment when the compression of the spring corresponds to the acceleration that is being measured. This condition is satisfied at the instant of making or breaking the circuit. The contact breaker comprises a binding post a, mounted on an insulating support y, and a non-insulated moving piece $z\,x\,t$. The stem of this piece, $x\,t$, passes with slight friction through the support o, and is drawn downward by a spring. The contact is regulated with

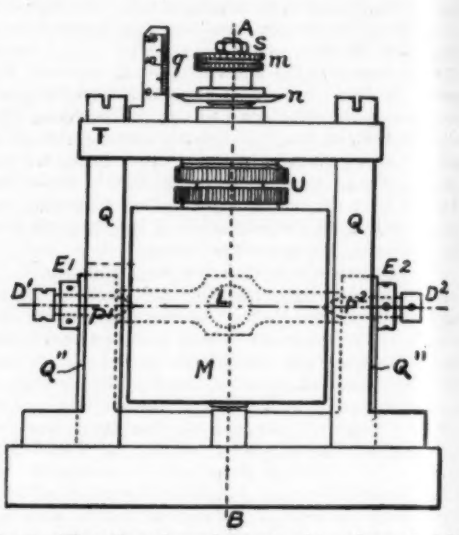


Fig. 3.—Elevation of accelerometer in a plane at right angles with that of Fig. 2.

precision by means of the platinum-pointed screw v, and its nut z. The contact-breaker is actuated by the piece k, attached to the cylinder M. The contact is broken when the cylinder strikes its stop T, and broken when the cylinder separates from the stop. The making or breaking of the circuit is indicated by a telephone, or recorded by a relay.

The measurement of acceleration is made by putting the telephone to the ear and regulating the tension of the spring R, by means of the screw $m\,n$, until the clicking sound ceases. The value of the acceleration at this instant is obtained by a simple calculation from the readings of the scale q and the graduated circle n.

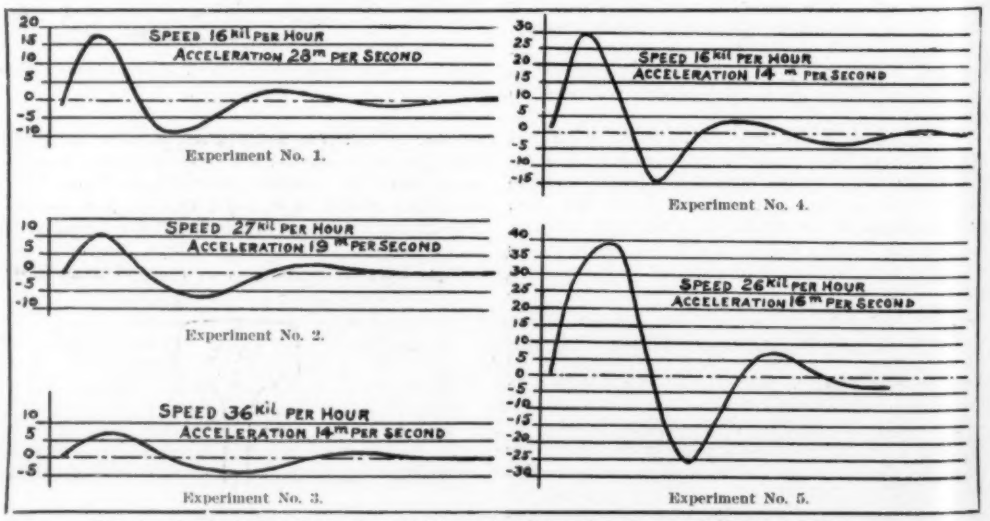

SPEED 16 KIL PER HOUR
ACCELERATION 28m PER SECOND
Experiment No. 1.
SPEED 16 KIL PER HOUR
ACCELERATION 14 m PER SECOND
Experiment No. 4.
SPEED 27 KIL PER HOUR
ACCELERATION 19 m PER SECOND
Experiment No. 2.
SPEED 26 KIL PER HOUR
ACCELERATION 16 m PER SECOND
Experiment No. 5.
SPEED 36 KIL PER HOUR
ACCELERATION 14 m PER SECOND
Experiment No. 3.

Fig. 6.—Vertical vibrations of a vehicle with solid rubber tires and shock absorbers.

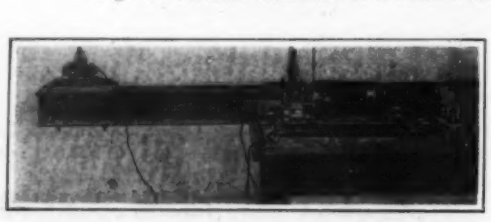


Fig. 7.—The accelerometer connected with an electromagnetic recorder.

This apparatus affords a means of measuring, so to speak, the degree of comfort that any vehicle offers to its passengers. It can be placed in any part of the vehicle in order to determine the accelerations that are produced at that point, and it is not too large or too heavy to be carried by a tramway, omnibus, or subway passenger.

In a heavy tramway car propelled by compressed air the instrument indicated vertical accelerations ranging from 2 to 4 meters per second, according to the condition of the track. Hence, as the acceleration of gravity

is about 10 meters per second, the apparent weight of a person or object in the car was increased or diminished by two tenths to four tenths its amount while the indicated accelerations were operative.

On the Metropolitan underground line No. 2, in an old first-class car with four wheels, the vertical accelerations attained 0.2 *g* (*g* denoting the acceleration of gravity) on tangents, 0.6 *g* on curves, and 0.8 *g* in braking. In the new cars mounted on two four-wheeled trucks the vertical accelerations are much smaller, ranging from 0.1 *g* to 0.28 *g*. The most violent and disagreeable shocks are produced when the brakes are applied on coming to a curve. There are two reasons for this: the brakes paralyze the springs, and the track is in bad condition owing to frequent braking at the same point.

On the floor of an automobile cab going 17 miles per hour on concrete pavement the vertical acceleration may attain 0.65 *g*. Hence, a person of 150 pounds weight, sitting on the floor of the cab, would be alternately pushed downward and pulled upward with a force of nearly 100 pounds, which would certainly be very disagreeable. In practice these shocks are greatly mitigated by the elastic cushion on which the passenger sits, but these vehicles are far from comfortable.

In a horse-drawn cab (Victoria) with solid rubber tires going 9½ miles per hour on macadam and concrete, vertical accelerations of 0.2 *g* and 0.3 *g* were detected.

Automobile omnibuses showed maximum vertical accelerations of 0.41 *g* on good macadam, 0.32 *g* to 0.84 *g* on wood, and 0.66 *g* to 0.82 *g* on concrete, at a speed of 12½ miles per hour. On very bad concrete pavement accelerations equal to 1 *g* were measured with a speed of only 7½ miles. The starting of the motor, while the vehicle was still at rest, produced a vertical acceleration of 0.14 *g*.

Various tires, suspensions, and shock-absorbers can be compared by placing the accelerometer on a vehicle which is equipped with each of these devices in succession and is moved over the same road, in which obstacles have been placed at regular intervals. In this case it is more convenient to keep the vehicle at rest and to represent the road by two cylinders, about six feet in diameter, rotating beneath its wheels.

This comparative study may be completed by making a graphical record of the displacements of the chassis with respect to the axles. Such a record is easily obtained by means of the flexion recorder shown in Fig. 4. In this apparatus a cylinder covered with paper rotates in contact with a pencil which is impelled in one direction by a wire attached to the bearing of the driving axle and in the opposite direction by a spring. The apparatus is placed on the floor of the vehicle.

The following table gives the results of a series of experiments in which the same vehicle was equipped, first with pneumatic tires, then with solid rubber tires and shock-absorbers. (In this table and in Fig. 5, the unit of acceleration is 1 meter-per-second-per-second = 0.1 *g* nearly.)

	Pneumatic Tires.			Solid Tires and Shock Absorbers.		
Number of the Experiment.....	1	2	3	4	5	6
Speed in kilometers per hour....	16	27	36	16	26	34
Obstacles met per minute.....	43	73	102	45	74	....
Maximum vertical acceleration of chassis after passing an obstacle.	28	19	14	14	16	25
Deflection of springs, millimeters.	17	10	7	30	40	....

The accelerations are plotted, as a function of the speed, in Fig. 5, which shows that pneumatic tires are inferior at speeds below 30 kilometers (about eighteen miles) per hour, but greatly superior at higher speeds, to solid tires with shock-absorbers. Fig. 5 also shows a profile of the obstacles used. The tracings made by the flexion recorder in five of the experiments are reproduced in Fig. 6. In experiment six the wire broke. The maximum ordinates of these curves represent the deflections given in the table above. The curves show that, in regard to the *amplitude* of the "jolt," pneumatic tires are superior at *all* speeds to solid tires and shock-absorbers.

The vibrations and accelerations produced in buildings by the passage of heavy vehicles are divided into three classes—dangerous, tolerable, and negligible—by a commission which the Automobile Club of France and the Central Society of Architects have jointly selected for the study of this subject. When this scale of vibrations has been fixed it will merely be necessary to place in the building under investigation three accelerometers adjusted to read dangerous, tolerable, and negligible accerations, respectively. The record may be made on a rotating cylinder coated with lamp-black, by a stylus moved by an electromagnet connected with the accelerometer (Fig. 7).

In conclusion, we give a few measurements of acceleration made on the ground or floor near motors. On a Seine passenger boat we have measured accelerations of 0.07 *g*, corresponding to vibrations 1/12th inch in amplitude. The reversal of the engines may cause an acceleration of 0.15 *g*. Accelerations of 0.07 *g* were noted in some stations of the Paris subway and the meeting of two autobuses produced an acceleration of 0.14 *g* on a Paris bridge.

In the frames of some machines we have found accelerations exceeding 1 *g*. In these conditions, any object placed on the frame will be lifted by a force greater than its own weight. It is for this reason that objects crawl off the tables and fall to the floor, in workshops and factories.

Prehistoric Man and His Early Efforts to Combat Disease*

Some Interesting Experiments Reproducing Primitive Surgical Methods

By T. Wilson Parry, M.A., M.D.

THE Stone Age must be regarded merely as a stage of culture, as every nation and people on their emerging from an animal to a human level, however low, starts with its "Stone" Age, passes through its "Copper" or "Bronze" Age, thence through its "Early-Iron" Age, till it eventually arrives at its Historic period. The anthropological world is indebted to the late distinguished antiquarian, Lord Avebury, for suggesting the division of the great Stone Age into two parts—namely, the Palæolithic or Old Stone Age and the Neolithic or New Stone Age.

Palæolithic man was a hunter living at first on the banks of rivers ("river-drift man" he was then called); then he took to dwelling in caves (cave man). We find him in this last capacity as an artist, showing much ability and even some genius.

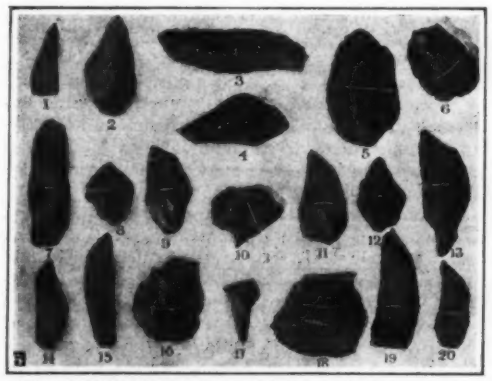
Neolithic man was of a different type. I think he may best be described as a farmer, a builder, and a surgeon. The Neolithic period is divided into three parts: (1) the Campigny period, (2) the Robenhausen period, and (3) the Carnac period. It is this last period that will specially interest us now, as we have absolute and certain proof that during this period the surgical operation of trephining was performed.

PRE-PALÆOLITHIC MAN.

To begin at anything like a beginning we must hark back to times much more remote than these. In pre-palæolithic days man was little above the lower animals. The picture that I have of the earliest primitive man at present is an admixture of Pithecanthropus erectus and the Piltdown lady. With the former's cranial capacity of 850 cubic centimeters and the latter's simian lower maxilla and canine tooth, we are getting dangerously near our cousins the anthropoid apes. A large male gorilla may have a capacity of 600 cubic centimeters, and there would therefore be much less distance between him and "the fossil man of Java" than exists between this latter and an average modern European cranium. I need not enter into the controversy as to whether these fossilized human crania belong to the early Pleistocene or late Pliocene period. The geologist has strong inclinations toward the former, while the anthropologist has much to say on the latter. I have faith that there are still to be unearthed anatomical surprises of unparalleled importance which when discovered will necessitate a constant rearrangement of ideas as fresh material is brought to light.

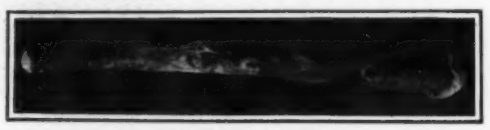
ANIMALS' SELF-CURATIVE INSTINCTS.

It is well known that animals possess strong self-curative instincts. Dogs and cats when indisposed will eat grasses that have a medicinal action, usually of an emetic or purgative nature. The fibrous-rooted wheatgrass,[1] *Triticum caninum*, is frequently eaten by the former. If an animal has been injured it is noticed continually to lick the affected part, which is a somewhat crude combination of our modern fomentation and massage. Prehistoric man would most certainly have licked his wounds. Later, when he had lost some of his earliest animal instincts, he would observe what animals did and imitate them. Thus the use of hellebore[2] was believed to have been discovered from the goat.[3] Virgil tells us that dittany was "eaten by wild goats when they were shot with darts."[4] Pliny tells us that bleeding was taught man by the hippopotamus, "that intelligent animal finding himself plethoric, goes out on the banks of the Nile and there searches about for a sharp-pointed reed, which he runs into a vein in his leg, and having thus got rid of a sufficient amount of blood closes the wound with clay." Buffaloes, horses and camels are exceedingly fond of licking salt. Prezevalsky says: "On the Mongolian camels salt, in whatever form, acts as an aperient, especially if they have been long without it." Livingstone says that "the chimpanzee, soko, or other anthropoid apes will staunch bleeding wounds by means of their finger or of leaves, turf, or grass stuffed into them." Primitive man must have done likewise, only always a little more.



Selected Neolithic flint flakes and borers (Celeraine). No. 20 was used in trephining skulls (Figs. 1 and 4).

Upper right—Skull of female (21 years) trephined by flint flake. Time taken, 30 minutes. Lower right—Dry skull partially trephined by shark's tooth. Time taken, 1¼ hours. Lower left—Skull of male (44 years) trephined by obsidian knife (Admiralty Islands). Time taken, 30 minutes. Knife used shown in center. Upper left—Skull of infant (16 months) trephined by flint flake. Time taken, 15 minutes.



Hafted shark's tooth.

Illustrations representing experiments of different kinds of primitive trephining, with tools used.

THE INSTINCTIVE PERIOD OF MEDICINE.

The first period in the history of medicine is known as the Instinctive Period or the Period of Demonology. As embryology epitomizes evolution, so the study of the present-day primitive savage unfolds to us the larger history of prehistoric man. It was no doubt the twin mystery of disease and death that first stimulated man to think, that is why the medicine-man and the priest were one and the same individual at the outset. The position of the medicine-man in the tribe must have been a most exalted one. In a fascinating book just published on the American Indian, called "The Vanishing Race,"[5] this is well shown. "The Indian," it says, "aspires to be a great hunter, he seeks fame as a noble warrior; he struggles for the eagle feathers of distinction, but his greatest longing is to become a medicine-man and know the great mystery." Witchcraft and magic early took a chief part in the treatment of disease, and demonology reigned supreme for many millenniums. Demonology is based on "Animism," and this latter briefly consists in the belief in the influence of the spirits of dead persons. Animism has its beautiful as well as its hideous aspect. The wide belief among savage races that inanimate objects, as well as animate beings, are all possessed of a

* An abstract of a presidential address delivered before the North London Medical and Chirurgical Society, and published in *The Lancet*.

spirit has been well demonstrated by Maeterlinck's excellent allegory "The Blue Bird," which shows the happy side of this creed. The unhappy side is illustrated by the reverence bestowed on spiritual monsters and the propitiation required by them. The three chief theories of disease were: (1) the anger of a disaffected spirit, (2) witchcraft, or (3) offended spirits of dead persons. The Manitira,[1] a low race of the Malay Peninsula, believe that there is a separate disease-spirit for every illness, one for smallpox, one for inflammation of the hands and feet, and one for hæmorrhage; in the last-named case the spirit is thought to fasten itself on the wound of the individual and suck out his blood. The aboriginal New Zealanders[4] had a separate demon for each part of the body to cause disease: Tonga caused headache and sickness; Moko-Tiki was responsible for chest pains, and so on. In Brittany to-day similar pagan ideas are universally accepted, but under different auspices. The Breton's deities are neither Tonga nor Moko-Tiki, but if the Bretons are suffering from boils they offer prayers to St. Maudez; if from fevers they petition St. Gonery.[7] The earth from the tomb of this latter saint is considered a cure for any kind of fever. It is sold in little muslin bags and tied round the necks of the patients.

DEMONOLOGY THE REASON FOR TREPHINING.

It must have been but a short step for the first man, who, firmly believing in demoniacal possession and who, at the same time, suffered either from frequent fits, severe pain in the head of a periodic or paroxysmal nature, chronic hemicrania or unbearable Ménière's disease, to make an effort to free himself from his fetters. Life had become an intolerable burden to him, and he believed there was a devil inside his cranium that was petitioning somewhat persistently for liberty. The first operation must have been troublesome and tedious, not to mention its extreme danger. The medicine-man had to incise the scalp with a sharp piece of flint, arrest the bleeding, and scrape the bone. This would take many hours to perform, but the patient was helpful and anxious to get rid of his devil, and possessed that unflinching stoicism to pain that is characteristic of the savage. If the patient recovered, he was reverenced as a hero. If he died his skull was eagerly sought after. The trephined portion was removed by flint saws and pieces of bone, edged by part of the healed cicatrix, were removed. Either a hole was passed through this or a groove made for affixing a cord, so that it might be worn as an amulet to defend the wearer against the disease from which the dead man suffered. The first skull of this kind to which the attention of scientists was drawn was discovered by M. Prunières in the year 1868 in a dolmen near Aiguières. This observer mistook the hole with the smooth edges for an opening that had been made artificially after death for the lips, in the conversion of the skull into a drinking cup, a custom well recognized among savage tribes. It was left to Prof. Broca to interpret this, and he showed indubitably that the hole in the skull had been made during life and had been done by scraping.[8]

NEOLITHIC TREPHINING IN GREAT BRITAIN.

It might have been thought, considering the number of trephined skulls that have been unearthed in France, that the custom would have spread to the British Isles, as only the Channel separated the two countries, and we have evidence that no inconsiderable amount of traffic existed between the shores in Neolithic times. I have only been able to hear of three such skulls that have been discovered in this country, and would be most happy to be informed of any other specimens should they exist. The three specimens of which I know are the following: 1. A skull that was dredged from the bottom of the docks at Port Talbot, South Wales, in or about 1870–72. I have a photograph of this skull, which has been kindly lent to me by Mr. Thomas Gray. This skull shows a frontal excavation over the right supraorbital region. 2. An interesting specimen showing a ring-trephine, as if an effort had been made to remove a rondel of bone.[9] This specimen was excavated in the autumn of 1863 from a long barrow, near Bisley, by the late Dr. W. H. Paine, assisted by Dr. Henry Bird. I have to thank Mr. A. E. W. Paine, son of the first-mentioned excavator, for kindly furnishing me with a photograph. Prof. Arthur Keith, who has seen this specimen, states that "there is no mark of inflammation or disease on the bone." This probably belongs to the Bronze Age. 3. The third specimen is in the Northampton Museum. I can emphatically state that the three trephine holes in the form of a triangle, on the vertex of this skull, were not made during the Stone Age nor by any Stone-Age implements. All that is known of this specimen is that it was found "outside the British Camp called Hunsbery" in Northampton. On a modern skull I have made as exact a model as I can of the three holes, as regards size and relative position, and it is my opinion that they were made on the original not from any demonological reason, but as a means for suspending the skull as a trophy by a Bronze Age or later headsman. I have to thank Mr. Thomas J. George, curator of the Northampton Museum, for his kindness in sending me tracings[9] of General Pitt-Rivers's plates of this skull. It is probable that only one of these three specimens alluded to above is Neolithic.

MELANESIAN TREPHINED SKULLS.

In the Museum of the Royal College of Surgeons of England are six skulls of modern Melanesians that have been either partially or wholly trephined by natives of those islands. In three of these specimens a complete perforation has been made in the cranial bones, and in the remaining three either the outer table alone or the outer table and diploë have been removed. One, a male from New Britain, has a large hole measuring 28 millimeters by 34 millimeters in the right occipito-parietal region. The outer edge of this hole is thin, beveled and smooth, and shows a healed surface, demonstrating a successful operation. Of the five other skulls, all of which came from New Ireland, one shows two frontal scrapings. On the left side the outer table has been completely rubbed through and on the right is a circular scraping leaving a boss of bone in the center, which looks as if an attempt had been made to remove a small rondel of bone. In the third skull is a beautifully rounded perforation measuring 14 millimeters by 15 millimeters in the left frontal region. The edges of this hole show perfect healing. There is a diseased patch of bone with considerable erosion in the mid- and right-frontal region which demonstrates the obvious reason for this operation. The fourth skull is similar to the last in the fact that a large scraping (17 millimeters by 28 millimeters) has been made, probably as a direct counter-irritation to relieve severe or continuous headache, in front of an extensively diseased area of bone. In the fifth skull there is a large elliptical scraping, 48 millimeters by 35 millimeters, in the right parietal region. A deep furrow in the center of this scraping illustrates the method by which this was done. In the sixth and last specimen there is a large perforation, 23 millimeters by 40 millimeters, over the left frontal region, and part of this hole is filled up with fresh callus formed during the process of healing. All the cases have undoubtedly been done by scraping the bone with obsidian flakes. In Melanesia after the operation has been performed the scalp is replaced and simply bound into position by a bandage made of banana fibre. My thanks are due to Prof. Kieth for his courtesy in permitting me to describe these specimens in this paper.

NEOLITHIC METHODS OF TREPHINING.

Being anxious to ascertain how Neolithic man trephined living subjects with the crude materials at his disposal, I made a series of some 19 experiments both upon recent and dry skulls. (See illustrations.) When showing the results of some of these experiments to Prof. Keith he informed me of a pamphlet by the late Dr. Lucas-Championnière[10] in which I would find that several of my experiments had already been done by him. I was quite unaware of this brochure when making my tests. Referring to this pamphlet it appeared to me that Dr. Lucas-Championnière had only experimented with flint. The materials I used besides flint were obsidian, shark's teeth, shell, and slate. Flint I used both in the form of Neolithic scrapers and as a hafted sharp point to a bow-drill. This bow-drill, I may mention, is one of the oldest forms of mechanical contrivance. Obsidian I also used in two ways—first as an ordinary flaked scraper, and secondly as a hafted implement in the form of an Admiralty Island knife. I used two kinds of shark's teeth—a small variety, for an infant's skull, was obtained from the King's Mill Islands, and was identified by Mr. C. Tate Regan, of the Natural History Museum, as belonging to "*Carcharias glaucus* or a related species," while the larger specimen, which I used for adult skulls, was *Galeocerdo arcticus*. The shells I used were beach-worn specimens of *Ostræa edulis*.

For scraping a hole in bone, metal not being considered, there can be no better natural implement than a well-flaked piece of flint. When flint cannot be obtained, as in volcanic regions like the South Pacific Islands, obsidian makes a good substitute. Obsidian is a natural volcanic glass and can be flaked, in the same way as flint, by a sharp well-directed blow. Contrasting these two substances I would give flint the first place. A hard, sharp edge can be obtained in flint which is more resistant to counter-pressure than is obsidian. Both flint and obsidian when freshly flaked are excellent substances for surgical purposes by virtue of their smooth surfaces, which would be aseptic. The method I employed for scraping the trephine-hole with flint and obsidian was the following. With a suitable flake I scraped as nearly as possible along a single line. This line I gradually converted into a groove, which soon showed two more or less prominent edges. With a curved movement of the scraper I next attacked these edges until a depression had been produced in the bone which gradually assumed an elliptical shape. It was now only a question of time and manipulation to convert this elliptical depression into a circular one, and thence, having penetrated the inner table of the skull, to expose the dura mater and enlarge the foramen to the size and shape required. As regards the bow-drill I bored a succession of holes, some fifteen in number, in a circular manner on the site chosen. These I enlarged till they touched one another. The next step was to break down the edges between them with a sharp, strong flake, and then by means of sawing and scraping eventually to remove a complete rondel of bone. This is an extremely tedious and clumsy operation, and not in any way calculated to bear comparison with the simpler method of scraping. As regards sharks' teeth as surgical instruments, I am satisfied that there is no more excellent natural implement for boring holes in bone than a hafted shark's tooth. Its keenly serrated edges and its strong, sharp point make it an instrument invaluable to the primitive surgeon. It moreover possesses a natural flange which converts it into a trephine of undeniable utility, for the flange is so placed as to prevent the point penetrating too deeply to the wounding of the dura mater. A ring of holes (as in the case of the bow-drill), packed as closely as possible, followed by breaking down the bridges between them, makes a hole (after removal of the rondel) as clean and neat as the most fastidious chirurgeon could wish. Trephining by shell was probably never attempted by Neolithic man in Europe, though primitive man in the South Pacific Islands certainly used shell for this purpose, and shell knives and lancets for opening abscesses. It took me nearly 25 minutes to trephine the skull of a 9 months old infant, which in time bears most unfavorably with the same operation on a 14 months old child which only took 9½ minutes, or on a 16 months old child, which took 15 minutes. I used slate in one instance, but it took me nearly 50 minutes to make a small hole in the skull of a man of 44 years. The originals of my experiments are exhibited in the Historical Medical Museum, and I have to thank the curator, Mr. C. J. S. Thompson, for his kind loan of aboriginal trephined skulls.

CONCLUSION.

We have been looking back into the far-away past and have been endeavoring to piece together the history of prehistoric man from specimens of his handiwork that have been heirloomed to us by the sheltering hand of Nature, who has protected them for us either by covering them over with the debris of rock or hiding them under stalagmite or in the deep breccia in the floors of caverns. To this has been added a passing glimpse at the methods of present-day primitive tribes. Tylor says:[11] "The uniformity which so largely pervades civilization may be ascribed, in great measure, to the uniform action of uniform causes." Thus it is that the combination of these two parallel studies enables us to get a true insight into the life of prehistoric days.

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The Use of Marine Turbines

ALTHOUGH we have read of steam turbines for marine propulsion for a number of years, still the subject is a new one to many people. It may interest these to learn that of the Parsons type there are 12,360,000 horse-power in use at present, and of this enormous amount nearly 2,000,000 horse-power were added during the current year. Of the above power the greater part is used in war ships, and only 1,850,000 is found in commercial vessels. The reason for this is that, although the steam turbine is very economical in itself, when it can be operated at the proper speed in revolutions, this speed is entirely unsuited for the best propeller efficiency, and consequently a compromise had to be made on both sides, with unprofitable results. Another objection to the turbine for use in vessels was the impossibility to properly maneuver them in making landings, etc., so that a combination of reciprocating engines and turbines was occasionally adopted, the regular engines being used exclusively for maneuvering, and for backing, which ordinarily requires an entirely separate turbine; but this was obviously a makeshift, and an undesirable complication that did not meet with great favor. All this has now evidently been changed by the invention of reducing gears that will permit the turbine to be run at an economical speed, while the propellers are operated at their most efficient rate of revolutions, making a power plant that is more economical and compact than the popular reciprocating engines. These reducing gears also make it possible to maneuver with the turbine. So far there are four systems for gearing down the propeller speed: the regular gear wheels of Parsons and Westinghouse, the Fottinger hydraulic transformer and the electric drive, where the steam turbine operates a dynamo, which furnishes current to a motor attached to the propeller shaft. The latter system is said to be very promising, as the loss of power in the transformation is very small, and the speed and direction of the vessel can be regulated and altered very easily and quickly.

One of the Mysteries of Chemistry

Useful Reactions Where the Inducing Substance is not Changed or Consumed

THERE are a number of chemical reactions that are collectively known as catalysis, about which very little is as yet definitely known, although in a few of the known cases of seemingly catalytic action certain intermediate reactions have been determined that apparently explain these particular processes; but whether similar processes take place in all cases is by no means certain. In its broad application the term catalysis is applied to processes that are induced by the presence of substances that are apparently inactive, and take no part in the reactions, which may be either accelerated or retarded by the same. An example of catalysis is that of hydrogen peroxide which, in dilute solutions, decomposes but slowly into water and oxygen. If a small quantity of platinum black is added the decomposition becomes so rapid as to show considerable effervescence. This action is continuous as long as any of the original liquid remains, and there is no wasting or consumption of the platinum black, all of which can be subsequently recovered unchanged by filtration.

Catalytic reactions occur in all branches of chemistry, very many being known, and the catalysts occur in both solid, liquid and gaseous forms, although the most numerous class are solids.

In a recent lecture at King's College, London, Prof. P. Sabatier considered the subject of catalysis, and gave many examples of this intricate action, together with such explanation of the theories of the process as are available; and from this lecture the following abstracts are derived:

THEORIES OF CATALYSIS.

Berzelius, who first called attention to the phenomenon, offered no real explanation, but suggested that catalysis was due to a change in the polarity of the atoms concerned. The importance of a fine state of division of the catalyst has suggested a physical explanation, long unchallenged. According to this theory, when platinum black is introduced into a mixture of oxygen and a combustible gas (hydrogen, alcohol vapor, etc.), the gases are absorbed rapidly by the porous material which attracts them to its surface, and the gases thus absorbed are subject to increased pressure and a local rise of temperature, both of which conditions assist the chemical interaction of the gases. The products are immediately removed, and replaced by a fresh quantity of the original gases, and so the reaction continues. The heat, set free by compression and by the combination of the gases, accelerates the action, and the platinum may even become incandescent. The function of the catalyst is thus to produce a local increase of pressure and temperature, so as to render possible, apparently at ordinary temperatures, a reaction which normally occurs only at higher temperatures. Ostwald regards the catalyst simply as the accelerator of a possible reaction which would, without the catalyst, take place slowly, and sometimes so slowly as to be incapable of detection. This theory does not offer an explanation as to the attraction of certain gases and not others by the surface of the catalyst; thus, platinum black must be supposed to attract hydrogen and oxygen, but not aqueous vapor. Further, certain catalytic actions are effected by platinum foil or wire, as well as by platinum black. A platinum spiral, heated to expel gases from its surface, and held over methyl alcohol, causes oxidation of the vapor to formaldehyde, the heat generated keeping the metal incandescent. A large sheet of platinum foil, slightly heated and held above an unlighted Bunsen burner causes combination of the gas and air; the foil becomes incandescent and may start a flame. In these cases, the porous solid is not present. Moreover, in the physical conception of catalysis the important differences in the effects of various solid catalysts having the same structure and state of division, are ignored. Zinc oxide and titanic oxide are physically similar but act very differently on formic acid vapor at 300 degs. Cent. With zinc oxide, equal volumes of carbon dioxide and hydrogen are formed, while with titanic oxide, water and carbon monoxide alone are produced. The physical explanation of catalysis is not applicable to liquid and gaseous catalysts which form a homogenous mixture with the reacting substances. A rational theory of catalysis must be based on the chemical action of the catalyst which can unite with some of the reacting substances to form an unstable intermediate compound.

Two chemical systems, which are themselves stable though capable of undergoing change, such as hydrogen peroxide, and chromic acid solution mixed with sulphuric acid, will, when mixed, act catalytically one on the other, constituting reciprocal catalysis, the two changes taking place simultaneously in identical proportions. The hydrogen peroxide and chromic acid are both decomposed and the same quantity of oxygen is generated from each. This indicates that the cause of the decomposition is the formation of an unstable compound of 3 molecules H_2O_2 and 2 molecules CrO_4H_2. This compound is decomposed as quickly as it is formed, into free oxygen, water and chromium sesquioxide which dissolves in the sulphuric acid. This intermediate compound can be isolated by suitable means. When dilute solutions are used, instead of oxygen being evolved, a blue liquid is produced. The blue substance can be extracted with ether, and isolated by evaporating at —20 degs. Cent. At the ordinary temperature this substance decomposes into oxygen, water, and chromium sesquioxide. A similar example is the interaction of hydrogen peroxide and potassium permanganate, and the existence of an intermediate unstable compound must be assumed in this case also.

ORDINARY CATALYSIS.

By analogy, it may be concluded that the catalyst combines rapidly with one of the substances present, and the compound formed reacts quickly with the other substances, setting free the catalyst which can act again in the same manner indefinitely. The intermediate compounds can sometimes be readily detected, when they are stable at some other temperature than that of the catalytic reaction. This is the case in the production of ether or of ethylene from alcohol by means of sulphuric acid. Concentrated sulphuric acid combines with alcohol to form ethyl-sulphuric acid:—

$$C_2H_5.OH+SO_4H_2=SO_4H.C_2H_5+H_2O.$$

If the liquid be kept cold, no further change occurs. On heating to 80 degs. Cent. in the presence of an excess of alcohol, the latter reacts on the ethyl-sulphuric acid to give ether, which distils off, and sulphuric acid which again combines with alcohol:—

$$C_2H_5.OH+SO_4H.C_2H_5=(C_2H_5)_2O+SO_4H_2,$$

the sulphuric acid thus acting as catalyst in the reaction:—

$$2(C_2H_5.OH)=H_2O+(C_2H_5)_2O.$$

A small quantity of acid can in this way transform a large quantity of alcohol into ether. If the liquid is quickly heated to over 150 degs. Cent., the reaction is different. The ethyl-sulphuric acid is decomposed with formation of ethylene and sulphuric acid:—

$$SO_4H.C_2H_5=C_2H_4+SO_4H_2.$$

The acid thus formed acts again in the same way, serving as catalyst in the reaction:—

$$C_2H_5.OH=C_2H_4+H_2O.$$

The intermediate compound in both of these reactions is easily detected, since it is stable at a lower temperature. Another example is furnished by Squibb's method for the production of acetone. The vapors of acetic acid are passed over calcium carbonate at 500 degs. Cent. The initial reaction is evidently the formation of acetate:—

$$CaCO_3+2(CH_3CO_2H)=CO_2+H_2O+(CH_3CO_2)_2Ca.$$

Below 400 degs. Cent., the reaction produces calcium acetate which is stable at the temperature, but at 500 degs. Cent. the acetate is decomposed into acetone and calcium carbonate:—

$$(CH_3.CO_2)_2Ca=CaCO_3+CH_3CO.CH_3,$$

and a small quantity of calcium carbonate can thus change any quantity of acetate acid into acetone. In both these examples, it is impossible to overlook the intermediate compound which serves as a step in the reaction. But usually the intermediate compound cannot be detected with certainty because it is not sufficiently stable at any temperature to be isolated. This is the case in most of the catalytic reactions induced by platinum or finely divided metals. But some idea of what occurs can be formed by analogy. Platinum black, when introduced into a mixture of alcohol vapor and air, fixes oxygen on its surface in the form of a true chemical compound, such at PtO, and the oxide reacts immediately with the alcohol vapor to form aldehyde, the platinum being set free and acting again in the same way indefinitely. Similarly, reduced nickel placed in a mixture of hydrogen and benzene vapor, fixes hydrogen on its surface in the form of a thin layer of an unstable hydride, such as NiH_2. At a suitable temperature, about 180 degs Cent, this hydride reacts immediately with the benzene vapor, forming cyclohexane, and the nickel is regenerated and acts again in the same way.

It also frequently happens that the unstable intermediate compounds formed by the catalysts can determine the reaction in either direction. Thus, platinum black absorbs free oxygen and yields it again immediately to oxidizable substances, but it can also, by virtue of the same affinity, take oxygen from substances capable of readily losing it. When platinum black is dropped into hydrogen peroxide, the platinum immediately takes up oxygen, forming the unstable oxide, which decomposes at once. Platinum black thus acts as catalyst in processes involving the addition or the removal of oxygen, according to circumstances. Finely divided copper or nickel placed in an atmosphere of hydrogen, fix the gas temporarily and pass it on to other substances. Conversely, in the presence of substances capable of giving up hydrogen, these metals take up hydrogen, which is immediately set free. Thus aldehydes passed with excess of hydrogen over nickel below 200 degs. Cent. form the corresponding primary alcohols. Conversely, the vapors of the primary alcohols, passed over nickel at 250 degs. Cent. are decomposed into aldehydes and hydrogen. Cases of this kind are very numerous. In conjunction with Mailhe the author has shown that the vapor of phenol when passed over thoria at 450 degs. Cent. loses water and is converted into phenyl ether. Later, the author and Espil showed that a mixture of phenyl ether and water vapor, passed over thoria at 450 degs. Cent. readily forms phenol. The two reactions occurring at the same temperature necessarily do not proceed to completion. A similar inversion of the effect of the catalyst is often met with. The recent researches of Bourquelot have shown that emulsin, a soluble organic catalyst, not only effects hydrolysis of glucosides, but can very often lead to the formation of the same glucosides by dehydration.

The catalyst appears to play an active part in the reactions which it determines. The temporary combination of the catalyst with one of the reacting substances makes the reaction possible, and a small amount of the catalyst can change a large quantity of the reacting substances, because the catalyst is regenerated by the rapid decomposition of the intermediate compound. There is thus no definite relation between the mass or the active surface area of the catalyst and the weight of the substances which it can produce. The reactions will, however, be more rapid as the quantity of catalyst is greater. Their velocity will be, in some degree at least, proportional to the mass of the catalyst in a homogeneous system, or to the surface in the case of solid catalysts which act only at their surface.

This chemical conception of catalysis has led the author with his pupils to the discovery of new facts, which may be grouped under two headings, catalysis (1) by metals and (2) by oxides.

In a series of researches extending over nearly 17 years, in colloboration with Senderens, Mailhe, Murat, and Espil, it has been shown that the common metals iron, copper, cobalt, and especially nickel, in a fine state of division, such as is produced in the reduction of the oxides by hydrogen, carbon monoxide, or alcohol vapor, form active catalysts in processes of adding or withdrawing hydrogen, and in molecular decompositions.

The catalytic action of finely divided platinum had been used chiefly for effecting oxidation. Only in few cases had its power of effecting the addition of hydrogen been recognized. In 1897, the author discovered with Senderens, that in the presence of reduced nickel, free hydrogen at a very low temperature can rapidly change ethylene into ethane, and it has since been shown that this catalytic action of nickel is quite general and is capable of effecting the addition of hydrogen not only in known reactions usually carried out by means of ordinary reducing agents but also in other reactions which could not be effected by the old methods. The method employed by volatile substances is very simple; it is only necessary to pass them together with hydrogen in excess through a column of reduced nickel kept at a suitable temperature. In this way, nitro-compounds can be converted into amines, e. g., nitrobenzene into aniline. Ethylenic and acetylenic compounds are readily converted into saturated compounds. Aliphatic aldehydes and ketones yield the corresponding alcohols, and amines are readily obtained from nitriles, oximes and amides. Carbon monoxide and dioxide are converted into methane, and this may possibly be the basis of an important commercial process for manufacturing from water-gas or coal-gas a lighting gas rich in methane and having a high calorific power. The most valuable application of the new method is the formation of cyclohexane derivatives by the addition of 6 atoms of hydrogen to the benzene nucleus. By simply passing benzene vapor with hydrogen over reduced nickel at 180 degs. Cent., the benzene is completely converted into cyclohexane. In the same way, phenol is converted into cyclohexanol, and analine into cyclohexylamine.

Certain conditions are essential for the success of the process. The temperature must be kept within certain limits, which are wide in some cases, as with nitro- and ethylenic-compounds, but narrow in others. The reduction of benzene cannot be effected above 250 degs. Cent.; at higher temperatures cyclohexane loses hydrogen. The best temperature is usually about 180 degs. Cent. The catalyst should be prepared in the reaction

tube itself, by reducing with hydrogen an oxide as free as possible from chloride and sulphate. The oxide obtained by calcining at dark red heat nickel nitrate prepared from commercial nickel and nitric acid is generally used. The nickel is more active the lower the temperature at which it is prepared, and the lighter the oxide from which it is formed. The metal obtained by reducing the green hydroxide below 300 degs. Cent. is exceedingly active and often causes molecular changes in compounds subjected to catalysis. Nickel reduced above 750 degs. Cent. will not convert benzene into cyclohexane, but will change nitrobenzene into aniline. An essential condition is the conservation of the catalyst, the activity of which may be spoiled by impurities in the hydrogen or in the reacting substances. Chlorine, bromine, iodine and sulphur are specially harmful in the case of nickel. In conjunction with Espil, the author has recently shown that the humidity of the hydrogen has no unfavorable effect, and is favorable in certain cases. But while it is useless to dry the gas, it is necessary to purify it thoroughly. It has been supposed that traces of chlorine, bromine, iodine or sulphur would immediately render the nickel inactive, but this is not the case. Benzene containing 0.5 per cent of iodine can be converted into cyclohexane, and during an experiment lasting several hours, 150 cubic centimeters of the solution was treated. On breaking the tube, the first half of the column of nickel was found to have taken up iodine and was inactive, and the second half was unaltered and was capable of containing the reaction. Thus the destruction of the catalyser by iodine took place slowly through successive layers, and in the actual experimefit 250 cubic centimeters of cyclohexane could have been obtained before the tube became inactive. A similar result was obtained with benzene containing 10 per cent of carbon bisulphide.

Reduced nickel effects the combination of hydrogen with numerous substances, which need not necessarily be in the gaseous state. When a current of hydrogen is passed through a fatty oil, such as earthnut (arachis) oil at 180 degs. Cent., in which reduced nickel is suspended, the oleic esters are converted into stearic esters and the reaction is completed in a few minutes. The oil changes to a fat, which solidifies on cooling. This conversion of oils into fats is usually accompanied by deodorization. It is now the object of important industrial applications.

The Explosibility of Grain Dusts*

As a result of a number of explosions in grain mills and industrial plants, and more especially as a result of an explosion in a feed-grinding plant at Buffalo, New York, in June, 1913, by which thirty-three men lost their lives and upward of seventy were injured, a cooperative movement between milling interests generally and the Bureau of Mines was arranged for the purpose of making a scientific study of the explosibility of grain dusts, and of methods pertaining to the prevention of such explosions.

In order to make a laboratory study of the problem, samples of the following dusts were collected, and the conditions under which they were produced were studied:

1. Dusts produced during the process of elevating and handling grain, and known as elevator dusts;
2. Wheat-flour dusts from rolls, bolters, purifiers, conveyors, packing machines, etc.;
3. Wheat-flour dusts from beams, rafters, elevator heads, etc.;
4. Dusts produced during the cleaning of oats;
5. Dust from grinding white corn;
6. Dust from grinding yellow corn;
7. Dust from grinding oat hulls;
8. Oatmeal dust from packing machines;
9. Floor dusts from elevator sweeping;
10. Oat-groat dusts after aspirator.

Experiments were then started in the Bureau of Mines, Pittsburgh, to determine the ignition-temperature of these dusts, using the method of Wheeler.[1] This consisted in forcing the dust in a cloud through a glass tube, 3 inches in diameter and 55 inches long, against a heated platinum coil, which was 15.75 inches from one end of the tube. The temperature of the coil was obtained by a Pt-PtRh thermocouple, having its hot junction within the quartz tube upon which the coil was wound. Using this method Wheeler determined the ignition-temperature of many dusts, obtaining results varying from 805 deg. Cent. for sugar, 960 degrees to 1,035 degrees for starch, 990 degrees for oat husks, 995 degrees for grain (flour-mill) to 1,060 degrees for flour and 1,100 deg. Cent. for castor-oil meal. The results obtained upon grain dusts by the author varied from 995 deg. Cent. for oat and corn elevator dusts, 1,015 degrees for feed dust from dust collector, 1,020 degrees for ground oat hulls, 1,025 degrees for yellow-corn dust, to 1,115 degrees for wheat elevator dust and 1,235 degrees to 1,270 degrees for flour dusts. Wheeler worked with samples which had been dried at 107 deg. Cent., while the author used the samples as received from the mill.

While the work gave the relative ignition-temperatures it did not give the lowest temperature of ignition or the relative inflammability. This latter was determined by means of an apparatus developed in the Bureau of Mines. It consists of an explosion flash of about 1,400 cubic centimeters (85-36 cubic inches) capacity having two tubulars, a platinum coil, a device for driving a dust cloud against the coil, and a Crosby pressure-gage for measuring the pressure developed. In each determination 50 milligrammes (0.00176 ounce) of dust is forced in a cloud against the coil, which had been previously heated to a known temperature determined by a thermocouple. The temperature is that inside the coil and therefore higher than the actual temperature on the outside of the coil. The dust is ignited by the heated coil and a pressure developed within the flask, which is registered by the gage. The relative inflammability at any temperature is measured by the difference in the pressures developed within the flask.

Determinations were made of pressures developed by the different dusts, as received and dried at 105 deg. Cent., when they were forced against the coil heated to 1,200 degrees, 1,100 degrees, 1,000 degrees and 900 deg. Cent. As no standard has been taken for carbonaceous dusts, other than coal dust, Pittsburgh standard coal dust, which is very constant in its properties, and which is used as a standard in the Bureau of Mines, was taken as a standard and all determinations run against it and checked against each temperature.

Tables and curves indicate that most, if not all, the grain dusts are more inflammable than Pittsburgh standard coal dust, higher pressures being developed in most cases, and especially so at the lower temperatures. The results also seem to indicate that the dusts from oats and yellow corn are more inflammable than those from wheat or other grain.

It is interesting to note the difference in the inflammability of the dried and undried dusts. In nearly every case the pressure developed was appreciably increased after drying.

Experiments carried out by the Bureau of Mines[2] have shown that an explosion could be produced when there was only 0.032 ounce of coal dust suspended in each cubic foot of air, or one pound in 500 cubic feet of air. Since preliminary experiments indicate that many of the grain dusts have ralatively a lower ignition-temperature than many kinds of coal dust, and are relatively more inflammable, it may be possible that an ignition of dust of this nature might be produced with a smaller proportion per cubic foot than is necessary for coal dust.

The following causes have been assigned to many of the explosions in milling plants in this country and abroad:

1. Use of open lights, or naked flames, such as lamps, torches, gas jets, lanterns, candles, matches, etc.
2. Property fires.
3. Introduction of foreign material in grinding machines.
4. Electric sparks from motors, fuses, switches, lighting systems.
5. Static electricity produced by friction of pulleys and belts, grinding machines, etc.

The investigation has indicated that a large number of the recent explosions and fires have been caused by the introduction of foreign material into grinding machines.

It would appear that a possible means of prevention would be to devise some system by which the foreign material might be removed before it reached the mill. Other preventions suggested are: A complete electric-lighting system, the use of portable electric lamps instead of lanterns or naked lights, the inclosing of the electric-light bulbs in strong wire guards or protectors, and the possible use of vapor-proof globes, and the locating of all fuses, switches, starting boxes, motors, etc., at points where no dust is present. It is also advised to have the receiving bins from the grinding machines as small as practical with the operations, as increased size gives increased space for dust clouds and therefore opportunity for a more violent and destructive explosion.

* Notes from a preliminary report by David J. Price and Harold H. Brown, to the Millers' Committee of Buffalo, N. Y., and published in the *Chemical Engineer*.

[1] Report of R. V. Wheeler on the inflammability and capacity for transmitting explosions of carbonaceous dust.

[2] The explosibility of coal dust. Bull. 20, Bureau of Mines, p. 102.

Photo-Activity of the Blood

THE interesting observation has been made that the blood of a guinea-pig will produce in from 16 to 13 hours, on a photographic plate a few millimeters distant, the image of a stencil placed in front of it. "It demands further investigation," says *Die Naturwissenschaften* (Berlin), "to decide whether we have here the effect of rays emitted by the blood, or whether it gives off a gas which affects the plate" (Schlaepfer, Zeitschr. f. Biol. 1914).

"Since a very thin leaf of aluminium interposed prevents the effect it cannot be due to alpha, beta, or gamma rays. A layer of unglazed paper (matt papier) makes the image fainter but does not preclude its formation. Since after more than 7 hours of strong illumination a mere trace of the effect of light passing through the paper could be observed, the effect produced by the blood cannot be ascribed to light, for blood is capable of emitting merely a very minimal intensity of light, which would produce no effect on the far side of the unglazed paper.

"On the other hand the paper could easily be penetrated by gas. It can, in fact, be demonstrated that the blood gives off peroxide of hydrogen, as is proved by the turning blue of a piece of filter-paper which has been saturated with a solution of potassium, iodide, starch-paste and ferrosulpate, and then laid over the blood at a distance of 4 millimeters.

"But hydrogen peroxide is capable of attacking photographic plates. The effect is due to the red blood corpuscles only, and not to the serum. Hence it is not a case of photo activity, but of the emission of a gas, whose appearance in the blood was not hitherto known and is of considerable theoretic interest."

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625 F Street, N. W.,
Washington, D. C.

SCIENTIFIC AMERICAN SUPPLEMENT
Founded 1878
NEW YORK, SATURDAY, DECEMBER 5, 1914
Published weekly by Munn & Company, Incorporated
Charles Allen Munn, President; Frederick Converse Beach, Secretary; Orson D. Munn, Treasurer
all at 361 Broadway, New York

Entered at Post Office of New York, N. Y., as Second Class Matter
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The Scientific American Publications

Scientific American Supplement (established 1876) per year $5.00
Scientific American (established 1845) " 3.00
American Homes and Gardens " 3.00
The combined subscription rates and rates to foreign countries, including Canada, will be furnished upon application
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